Domesticating Infrastructure: Mumbai's middle class housing and rainwater harvesting

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Abstract

Housing is no longer merely a site of resource consumption, but also supplier of decentralised 'green' resources for Mumbai's middle classes and rainwater harvesting is pivotal to this shift as the first major environmental intervention. This thesis aims to assess how Mumbai's middle classes are responding to water shortage and environmental change through domestic rainwater harvesting. Rainwater harvesting is mandatory in newly constructed buildings and retrofits are becoming increasingly popular as the municipality promotes water saving initiatives. The responsibility for securing water resources in Mumbai's middle class households has thus been shifted onto the residents themselves at the same time as they strive to secure and improve their lifestyles.

This research draws on fieldwork in Mumbai from 2009 to 2011 to explore how rainwater harvesting is being governed, assembled and practiced by the rapidly growing but under-researched middle classes. A socio-technical framework is used to analyse the findings and this thesis draws three main conclusions: Firstly, housing is being repositioned as a water supplier, and thus a site for governing services, promoting middle class responses to shortage and allowing the municipality to roll back provision. Secondly, the domestication of water supplies through rainwater harvesting can accelerate the uptake of other environmental technologies within residential buildings by creating apertures in the socio-technical transition. Thirdly, rainwater harvesting facilitates the performance of middle class lifestyles by securing constant water supplies but servants can distance residents from resource use and influence uptake and effectiveness of these decentralised environmental services. Therefore, if these complexities are acknowledged, the domestication of water infrastructure through rainwater harvesting has the potential to open up Mumbai's homes to become more sustainable.

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ALM – Advanced Locality Management (residents' group)

BMC – BrihanMumbai Municipal Corporation (Now officially the MCGM, but still referred to as BMC even officially)

Chappals - Sandals

Colony – Gated community

Co-operative – a private co-operative housing society' where a share in the building is owned rather than the individual apartment

CRZ – Coastal Regulation Zone. Buildings cannot be constructed within 500metres of the coast

EcoHousing – a local green rating system for domestic buildings

Geyser – small electric water heater to heat water for bathing

GoI – Government of India

GoM – Government of Maharashtra

GRIHA - Green Rating for Integrated Habitat Assessment (Indian eco-rating system for built environment)

LEED - Leadership in Energy and Environmental Design (an eco-rating system for buildings developed in the USA)

LEED India - Leadership in Energy and Environmental Design adapted for India's climates

MCGM - Municipal Corporation of Greater Mumbai

MMRDA – Mumbai Metropolitan Region Development Authority

MNRE – Ministry of New and Renewable Energy

Pukka – Solidly constructed. Can also mean 'legitimate' and so legally built, as well as 'good'.

RWH- Rainwater harvesting

Salwar chemise – tunic suit

UPRA – Union Park Residents' Association

Vastu Shastra – Set of Sanskrit guidelines on how to plan a building. If followed then they create a passive building. (Sometimes referred to as Indian Feng Shui)

Watchman – the guard and handyman of an apartment building

Statement of copyright

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Dedication

To Paul Johnson 1985-2012.

Friend and colleague.

Chapter One

Introduction

Figure 1.1: Coastal defences in South Mumbai (Source: Author)

1.1 Introduction

The combined forces of a changing climate and rapid urbanisation are converging on Mumbai. Flows of water through Mumbai are shaped by a combination of infrastructure deficits, consumption practices, urbanisation, environmental changes and the disruption of extreme weather events (Kaika, 2005, Concerned Citizens' Commission, 2006, Gandy, 2006b). This thesis investigates how Mumbai's middle classes are responding to water shortage and environmental change through domestic rainwater harvesting and the wider implications of this for the city and for the uptake of environmental technologies.

Understanding these issues requires a critical engagement with: the governing of housing and water infrastructure; the installation and maintenance of domestic rainwater harvesting assemblages; and the practices using harvested rainwater in the middle class home. Rather than thinking about how water infrastructure is being controlled by policy elites, or how deficits are effecting the most vulnerable, this thesis seeks to understand the experiences and responses of the rapidly growing and heterogeneous Indian middle classes, who are often absent from academic and policy debates (Lemanski and Lama-Rewal, 2013). A socio-technical reading of these interventions helps to unpack the complex interactions within urban and domestic climate change responses. This analysis enriches our understanding of how urban experiences are (and are not) becoming entangled with the changing climate.

In this chapter, I explain the rationale for undertaking the research by introducing the domestication of water infrastructure, and debates surrounding urban water supplies and climate change vulnerabilities. This places the research within these debates and identifies areas that warrant further investigation, such as the Indian middle classes. I follow this rationale by laying out the aim of the research and the research questions that I address through the thesis. Finally I explain the structure of the thesis and the contribution of each chapter in addressing the aim before presenting the contributions that the thesis makes as a whole.

1.2 Research rationale

The underlying motivation for this research is the complex relationship between urban housing and the environment, through infrastructure interventions. The original brief came from an ESRC CASE partnership with the Building and Social Housing Foundation (BSHF) and was framed by urban climate change responses through housing in the Global South and suggested using Mumbai and Hanoi as case studies. I decided to focus on Mumbai as a rich and complex case study that could also have insights for other Asian coastal megacities (see section 4.2.1). The need to respond to climate change grows increasingly more urgent (The Stern Review Team, 2006) and the response of cities to climate change has become increasingly prevalent in the agendas of global organisations such as The World Bank (The World Bank, 2010, Hoornweg et al., 2011) and UN-HABITAT (2011).

Coastal mega cities in the Global South, such as Mumbai (see fig. 1.1), are the most at threat due to changing weather patterns and rising sea levels (Nicholls et al., 2008, The World Bank, 2010). Cities have also been identified as contributing significantly to climate change through emissions of greenhouse gases and consumption of resources. However, cities are also seen as part of the solution to limiting climate change by building resilience and mitigating emissions through efficiency and technological approaches (Rees and Wackernagel, 1996). Cities, therefore, have a unique position contributing to both the causes and solutions of climate change (UN-HABITAT, 2011, The World Bank, 2010). The Indian Government's position in international climate change negotiations is in opposition to binding carbon emissions targets for developing countries. This position is supported by some academic debates, which argue that countries in the Global South should not prioritise the mitigation of climate change as it might distract from other important agendas, such as economic development and poverty alleviation (Fisher, in press, Satterthwaite et al., 2007).

The focus of this research evolved from this starting point and now engages with middle class responses to water shortage and environmental concerns, specifically through domestic rainwater harvesting – how they are governed, implemented and experienced – through empirical data collected in Mumbai. The turning point came during my first fieldwork period in Mumbai when I uncovered middle class concerns over water provision embedded in this complex city and bringing together issues of class anxiety, infrastructure deficits and environmental concerns.

1.2.1 Water infrastructure deficits and vulnerabilities

There are two main reasons for the position of water at the heart of environmental change discourses and responses in a city with such a visible connection and yet troubled relationship with water. Firstly, the coastal position of Mumbai and its high-density built-up area, combined with the monsoonal climate, make it particularly susceptible to flooding and water shortages (Timmerman and White, 1997, Yeung, 2001). Secondly, there is a chronic shortage of mains water supply in Mumbai and the municipality is struggling to update the infrastructure (Gandy, 2008).

Sea level rise, drought, water shortage, flooding, unpredictable precipitation patterns, cyclones… Water is an urgent environmental concern for many urban populations, especially large coastal cities in the global South (Timmerman and White, 1997, Yeung, 2001). Part of this vulnerability is due to current infrastructure deficits, and the interaction between responses to climate change and infrastructure deficits is important in the rationale of this research. The motivations of interventions may be blurred between resource security and climate change responses, which is central to this research.

1.2.2 Domesticating infrastructure

Residential buildings are an important scale at which to investigate environmental technologies and governance. Housing brings together services, both through large scale centralised infrastructures and small-scale decentralised systems, for use in a variety of practices. I use domestic buildings as a lens through which to view the governing, installation and use of rainwater harvesting. Housing is a nexus of infrastructure and is a point at which social, natural and technical elements are drawn together to become hybrids. This research brings together the domestication of technology (Shove, 2003a), water (Swyngedouw, 2004) and nature (Kaika, 2004) to consider what it means to domesticate environmental infrastructure through the use of rainwater harvesting in the apartments of Mumbai. The concept of domestication is the taming of disparate elements by bringing them into the home. In this thesis I use the concept of domestication to analyse the re-scaling and controlling of service provision in residential buildings.

1.3 Aim and research questions

This research aims *to assess how Mumbai's middle classes are responding to water shortage and environmental change through domestic rainwater harvesting*. This aim is reached using the above rationale as a starting point and a series of research questions to guide the collection and analysis of empirical evidence:

How is rainwater harvesting governed in Mumbai?

How is rainwater harvesting assembled and installed in and around middle-class domestic buildings?

How is harvested rainwater used in middle-class homes?

These research questions are addressed through the analysis of empirical evidence collected during two fieldwork periods in Mumbai. This led to an investigation from three angles representing different spatial and temporal scales, prioritising different aspects of the study and involving varying actors. The analysis of this qualitative data is influenced by socio-technical approaches, discussed in Chapter Two, to draw out the significance of each angle in the domestication of environmental infrastructures.

1.4 Focussing on Mumbai's middle class housing and rainwater harvesting

> "For the first time in its history the city's municipal corporation and its water engineers have been engaged in educational and outreach programmes to encourage changes in household water use and the introduction of water-saving technologies. At the same time, however, the spread of more profligate uses of water by the city's middle classes reflects changing patterns of consumption that serve to undermine any efforts at water conservation." (Gandy, 2006b: 19)

Gandy points to the tension between the water saving and alternative sources promoted by the Municipal Corporation of Greater Mumbai (discussed in Chapter Five) and the everyday practices of Mumbai's growing middle classes (as explored in Chapter Seven) that lies at the heart of this thesis. This leads to the specific focus on domestic *rainwater harvesting in middle class Mumbai*. This section thus unpacks the subtitle of the thesis to provide a rationale by considering the four further foci of the thesis: the choice of Mumbai as city; identifying the middle classes as an important and under-researched population; investigating housing as the site for addressing water shortage and environmental issues; and focussing on the intervention of rainwater harvesting.

1.4.1 Mumbai

"Bombay is a crowd" (Naipaul, 1990: 1). The World Bank (2010) has identified Mumbai as being the third most populous urban area in the world at 18.84 million in 2006. Out of the 25 largest mega-cities[1] in the world, 17 are coastal and the majority of these are in Asia (Timmerman and White, 1997, Yeung, 2001). Mumbai is a mega city on the west coast of India and

[1] Mega-cities are urban areas with populations in excess of 10 million people.

has been identified as one of the cities most vulnerable to climate change, due to its position as well as the density of its population and the high levels of urban poverty (Nicholls et al., 2008). Mumbai is at once a typical example of an urban area at risk from climate changes and an exceptional city due to its size, levels of inequality and infrastructure deficits.

The study of world and mega cities has been critiqued as narrowing the focus of urban studies and, at the same time, moving the gaze away from the 'ordinary city' (Robinson, 2002, Robinson, 2006). However, the multiplicity of Mumbai means that, although it has specificities, lessons learned about climate change responses have the potential for application elsewhere. This research is not a quest for the paradigmatic city (Nijman, 2000) but rather an exploration of one city that might have implications for the many cities in similar situations. The potential within mega cities for responding to climate change and water shortage may depend on how development is governed and infrastructure deficits dealt with.

There has been a great deal of research conducted in Mumbai, particularly focussing on housing and water infrastructure of the urban poor (see for example Gandy, 2008, McFarlane, 2008b). The infrastructure deficits of both these systems shape the everyday experience for the 60% of Mumbai's residents who live in informal settlements, but are also felt by the middle classes. It is thus unsurprising that the nexus of these systems in the under-researched middle class apartment building provides the conditions for environmental responses.

1.4.2 Middle classes

There is limited research on the Indian middle classes and their relationship with infrastructure and the environment (Mawdsley, 2004, Lemanski and Lama-Rewal, 2013). Studies of urban India have focussed on the urban poor majority, sometimes using the elites as a counterpoint to demonstrate inequalities but largely overlooking those in the middle (Lemanski and Lama-Rewal, 2013). In 2006 the journal *Critical Asian Studies* ran a special issue on class in South Asia that decries the decline of class analysis in the subcontinent (Herring and Agarwal, 2006, Chibber, 2006) and points to a renewed focus on India's middle classes (Fernandes and Heller, 2006, Harris, 2006). There are notable difficulties in defining India's large and heterogeneous middle classes (Fernandes, 2011, Mazzarella, 2011), as discussing in Chapter Three when I draw out a specific understanding of the Mumbai's middle classes for this research. However, the global, crosscutting nature of the Indian middle classes places them as a significant population to study (Varma, 2007, Fernandes, 2000, Brosius, 2010).

McFarlane and Rutherford (2008) suggest that the links and juxtapositions between the urban networks across the Global North-South divide is an under-researched area and I suggest that study of the middle classes could address this. The middle classes are also vulnerable to climate change. If homes and businesses are damaged they may struggle to buy a solution as the elites might or build anew as the urban poor might. Therefore I discovered most domestic actions and interventions to address infrastructure deficit and climate change within middle class housing.

1.4.3 Housing

Literature on Mumbai's housing, infrastructure and climate change vulnerability debates have been rightly dominated by discussions of the poorest citizens. This is due to the majority of citizens living in informal settlements and the serious and specific challenges faced by the urban poor (Das, 2003, Mukhija, 2001). Access to adequate housing remains a pressing issue for Mumbai's urban poor, which is exacerbated by continuing migration and urbanisation. The housing supply problem and the municipality's attitude to informal settlements are closely linked to the lack of infrastructure supplying services to the urban poor. People living in Mumbai's informal settlements or on the pavements rarely have legal connections to mains supplies of water, sewerage or electricity (Graham et al., 2013). There are several plans to develop many of Mumbai's informal settlements into luxury apartments. This is one motivation for the municipality's reluctance to upgrade informal housing, as this might be seen as legitimising those residents' right to the city. Thus services continue to be provided through decentralised infrastructure and middlemen, and means that the urban poor end up paying more for their precarious and intermittent access to services. Mumbai's water infrastructure is discussed in further detail in Section 3.6.

Housing of Mumbai's extremely wealthy residents is sometimes discussed as a counterpoint in this literature, but the middle classes are rarely encountered. These debates are an important but offer only a partial view of housing in Mumbai. In this thesis I identify middle class housing as a nexus of infrastructures and site of consumption and therefore a crucial arena for addressing climate change. In Chapter Five, I discuss how perceptions of housing are shifted by these interventions and how this conversely makes housing a key space for responses.

1.4.4 Rainwater harvesting

Rainwater harvesting was identified as the leading response in Mumbai, during my preliminary fieldwork (see Section 4.3). This is unsurprising due to the insufficient centralised water infrastructure and increasing pressures from urbanisation and climate change. As Harvey (1996) points out, it is resources that are needed by all society, including the wealthy middle classes, that gain the attention of politicians and businesses and thus water provision is a focus of action in Mumbai. This highlights justice debates around the focus of responses by political elites and the promotion of solutions that benefit the middle classes at the expense of the urban poor. Water infrastructure is the focus of several debates centred specifically on cities in the Global South (Smith and Ruiters, 2006, Gandy, 2004, Bakker et al., 2008) and especially Mumbai's infrastructure deficit (Gandy, 2006b, Gandy, 2008, McFarlane, 2008b). In Chapter Three I describe the water infrastructure of Mumbai and how constant supply is maintained in Mumbai's middle class homes, including how rainwater harvesting fits into this supply system. Rainwater harvesting has been discussed as a solution to water shortages in the Global South; both in rural (Kahinda et al., 2007) and urban (Handia et al., 2003) contexts. Pandey et al (2003) use historical data to suggest that some communities in India may have developed rainwater harvesting to adapt to changing climates in the past, rather than migrating to other areas. Chapter Six explores how rainwater harvesting is now being assembled in contemporary Mumbai to address water shortage.

1.5 Thesis Structure

Chapter Two aims to establish the socio-technical lenses that I use to view the empirical data throughout the thesis. These approaches are urban political ecology, assemblages and socio-technical transitions, and form the basis for understanding the city, its systems and processes of change. In Chapter Three I introduce Mumbai as the case study city through an exploration of its middle classes, housing policy and water infrastructure. This chapter also looks at the historical development of Mumbai's housing and introduces contemporary housing of the middle classes. The water infrastructure is explained from its historical development through to contemporary city-wide deficits and the portfolio of provision to middle class homes. Rainwater harvesting is introduced as the nexus of these other systems and policies, and its transition from historical rural water source in Northern India to contemporary urban environmental technology is discussed. Chapter Four is a discussion of the methods used to collect the data in Mumbai. The strengths and weaknesses of methods for addressing the research questions are investigated along with the specific issues encountered researching the middle classes and challenges that were overcome during the fieldwork. In this chapter I also deal with issues of gender when conducting research in India and the large number of researchers that Mumbai attracts.

In Chapter Five I consider the governance of the environment through housing in Mumbai, particularly the re-casting of housing as a supplier of water by rainwater harvesting. The role of public authorities, institutions and developers, and private residents in the various modes of governing the environment and shaping housing provision are considered. Chapter Six sites and embeds rainwater harvesting in buildings by considering how systems are assembled. This chapter uses data collected during site visits to interrogate the processes involved in designing, installing and maintaining rainwater harvesting systems. Chapter Six also considers the relationship of rainwater harvesting to other environmental technologies in a building and city. Chapter Seven focuses on the water practices of the middle class home to assess how rainwater harvesting is experienced. I investigate the ways in which harvested rainwater is used in domestic tasks and the metabolic flow of water through the building. The complexities of these practices are drawn out to explore effects on technology uptake and boundaries. Chapter Eight draws together these threads of enquiry in relation to the research questions and explores the conclusions from the proceeding chapters. This reveals future research possibilities, policy implications and dissemination pathways.

1.6 Contribution of the thesis

In addressing the above questions, within the rationale and context presented in this chapter, this thesis makes a contribution to our knowledge of urban environmental responses through infrastructure in the Global South. Mumbai's middle classes are an under-researched population and this research addresses this gap in the literature, which is important due to the environmental responses identified in middle class housing. Placing emphasis on water infrastructure moves away from North-centric environmental debates focussed on energy and emissions (Moser and Satterthwaite, 2008).

A socio-technical reading of these interventions increases our understanding of the complex interactions and socio-technical lenses have not been widely used to look at infrastructure in the Global South. This thesis is informed by urban political ecologies, assemblage theory and socio-technical transitions to analyse the nature of Mumbai's infrastructure and climate change responses, and to understand the processes of change within them. This analysis leads to three main conclusions: Firstly, housing is being repositioned as a water supplier, and thus a site for governing services, promoting middle class responses to shortage and allowing the municipality to roll back provision. Secondly, the domestication of water supplies through rainwater harvesting can accelerate the uptake of other environmental technologies within residential buildings by creating apertures in the socio-technical transition. Thirdly, rainwater harvesting facilitates the performance of middle class lifestyles by securing constant water supplies but servants can distance residents from resource use and influence uptake and effectiveness of these decentralised environmental services. Therefore the domestication of water infrastructure through rainwater harvesting has the potential to open up Mumbai's homes to become more sustainable if we acknowledge the complexities of interactions in residential buildings.

Chapter Two

Socio-technical framing of rainwater harvesting

Figure 2.1: Water tanker (Source: Author)

2.1 Introduction

"The notion that technology and things shape and are shaped by social, economic and political considerations makes good intuitive sense…" (Shove 2003: 46). Elizabeth Shove, and other scholars working with socio-technical ideas, find that the social and technical are co-produced (Heynen et al., 2006a, Bulkeley et al., 2013). A socio-technical approach is a way of understanding the relationships between people, the environment and technology at different scales. In particular I use urban political ecology ideas to explain that cities are socio-natural and how water changes as it flows thorough urban infrastructure. I then use assemblage ideas to explain how different people and things interact to harvest rainwater in domestic buildings.

In this chapter I introduce the socio-technical approaches that run through this thesis to understand infrastructure in Mumbai and create the basis of a conceptual toolkit to frame later discussions. Firstly I expand on the concept of domesticating infrastructure, which I introduced in Chapter One, and this demonstrates the central role of housing and how it relates to water infrastructure in this research. This also includes a discussion of taming nature. Secondly, I introduce urban political ecologies, which I use to explain how cities are formed from the social and the natural. These concepts also show that infrastructure is inherently political informs my understanding of governing rainwater harvesting. Thirdly, assemblage concepts are introduced to focus socio-technical ideas onto smaller scales to understand specific systems, and to begin to unpack how systems change over time. I also find assemblage useful for framing governance and for considering how domestic practices relate to other parts of the home and the city. Fourthly I discuss debates on climate change vulnerabilities and responses in the Global South to explore the setting for these socio-technical concepts and lead into the context introduced in Chapter Three. Finally, I draw together these discussions to form the basis a conceptual toolkit that is strengthened during the empirical analysis.

The concepts that I discuss in this chapter will be combined with other approaches to analyse how rainwater harvesting is being governed, assembled and practiced. In Chapter Five I add governance to urban political ecology and assemblage to unpack the how rainwater harvesting is being controlled and delivered by various stakeholders. In Chapter Six I place rainwater harvesting assemblages within socio-technical transitions to demonstrate the transformative effect that could take place and lead to further domestication of infrastructure. In Chapter Seven I use everyday practices to discuss how harvested rainwater is used in the assemblages of Mumbai's middle class housing.

2.2 Domestication

Housing is an important nexus of urban infrastructure that forms the site of my empirical investigations and frames my understanding of infrastructure. The concept of 'domestication' denotes the taming and re-scaling of infrastructure to fit into the home and has been used by several academics to explain the relationship between nature, cities and homes. Elizabeth Shove (2003) writes about how the uptake and adoption of a new technology into the everyday practices of the home can be thought of as domestication. Shove uses this domestication of technology concept to explain how comfort is achieved in modern homes in the UK and USA. This is part of her wider discussion of the co-production of comfort through the interdependencies of technology and everyday practices. Thus for Shove (2003: 55) domestication takes places when technology is "… adapted, incorporated and converted…" through everyday practices in the home, and this informs my analysis of everyday practices in Chapter Seven. Shove goes on to argue that, although available technology shapes practices, the way in which technology is brought into homes and used in accordance with residents' requirements also feeds back into and changes the socio-technical system. Maria Kaika (2004, 2005) uses domestication as part of her explanation of how nature is tamed and brought into the modern home. In particular she uses the domestication to conceptualise how modern western homes tame, control and sort nature, and parallels can be seen in middle class homes in Mumbai. Kaika understands domestication as both bringing nature into the homes and taming it (such as piped potable water) and also the exclusion of unwanted natural elements (such as sewage or pollution). In the discussion of metabolisms in Section 2.3.1, I explain that these unwanted elements can be created though water uses in the home, and are then subsequently excluded. Eric Swyngedouw (2004) discusses the domestication of water in Guayaquil, Ecuador, as an extension of the urbanization of water by bringing it into buildings. Swyngedouw uses domestication to explain the ways in which the middle classes and elites are bringing water into their homes as part of the bourgeoisification of Guayaquil. Swyngedouw sees the concepts of domestication as an extension of urbanisation and the commodification of water. For Swyngedouw domestication is part of the urban political ecology of water and is essentially about power: over water as part of the ecological conquest; and as a demonstration of class position within the stratified water provision. The ability to domesticate your water and bring it into the home is an expression of social power and this informs my ideas about Mumbai's middle class and infrastructure governance.

Although most concepts of domestication are concerned with reducing scale and bringing elements into the home, Ayona Datta (2013: 171) discusses the domestication of neighbourhoods in informal settlements in Delhi, where 'the ideology of home and family' protect all the residents in an area. This type of domestication conceptualises the home as extending out and incorporating the area into its sphere. This is a concept I return to in Chapter Seven through the stretchable and permeable boundaries of the middle class home (also see Dickey 2000). In this thesis I explore how the processes of governing, assembling and using rainwater harvesting are domesticating infrastructure through rescaling and taming.

Nature is threatening cities as the climate changes, after attempts to tame, control or remove it from the urban realm over the last two centuries (Kaika, 2006, Kaika, 2005). Crises and failures of the system are often seen as moments in which the infrastructure of a city is suddenly foregrounded (Graham and Marvin, 2001, Kaika, 2005). Domestic water supply is therefore presented as an autonomous 'black boxed' supply in much of the literature and only becomes visible when it breaks down (Graham, 2006, Shove, 2003a). This 'black boxing' of infrastructure processes may not be present in Mumbai to the same extent as other cities (Graham, 2006). Trentmann (2009) argues that disruption is normal in most systems (not just in the Global South) and that the reaction to these disruptions depends on the degree to which they are accepted as a normal part of practices. In Mumbai shortages and failures are endemic and the infrastructure is highly differentiated and flexible as a result (as described in Section 3.6). Thus it could be argued that the everyday occurrence of inadequacy and failure of Mumbai's infrastructure keep it visible. Those households that do have a piped mains water connection only receive water for a few hours per day and store it in tanks as well as using other forms of supply (see Section 3.6.2). Thus water is brought into homes and domesticated in different ways. The visibility of services has the potential to make middle class residents mindful of use and could be used to influence consumption behaviour. However a recent study of installing smart meters to measure domestic electricity consumption in UK homes found that behaviour changed in the short term but residents later became used to the presence of the meter and the infrastructure was backgrounded again (Hargreaves et al., 2013). So Mumbai's middle class residents may become used to dealing with these failures meaning that it takes an even larger sudden catastrophe to instigate fundamental changes (Trentmann, 2009).

In Mumbai I have found that the unpredictable monsoons and the floods of 2005, exacerbated by mis-management, have encouraged citizens to save water or install rainwater harvesting. The attention garnered by these catastrophic failures is used by the municipality to frame policy interventions, even though the problems are endemic (Municipal Corporation of Greater Mumbai (MCGM), 2013, Municpal Corporation of Greater Mumbai, 2003). This echoes the wider environmental idea that politicians and civil society should not wait until there is a catastrophe before acting, even though there is more public support when the threat is immanent . The framing of water shortages has dramatic impact on the governance of urban water supply (Bakker, 2010) and drought is a natural phenomenon that affects many parts of the world but water shortage is a social construct created by increased wants (Kaika, 2005, 2006). Thus the move from natural phenomenon of drought to the social construct of water shortage frames urban political decisions about infrastructure (Swyngedouw, 2004).

This commodification can lead to the privatisation of a natural resource and the marketed supply networks (Bakker, 2003b). Privatization of water is a contested concept and the privatisation of water supplies has been undertaken across the world to varying degrees (Bakker, 2003a, Bakker, 2007, Swyngedouw, 2000). In India the water supply has not been privatised in a formal way, however, some parts of supply have been taken on by private endeavours; either for profit, such as the water tankers of the 'Water Mafia' (see Graham et al., 2013), or to build personal resilience to fluctuations in supply, such as the rainwater harvesting, blurring state and non-state boundaries (Bulkeley and Schroeder, 2011). I suggest in Chapter Five that the domestication of water infrastructure through the governing and supplying of water, and other services, at the building level could reduce the amount of corruption experienced by the residents because of stakeholder involvement (Asthana, 2008). The complicated and differentiated supply, and therefore governance, of water in Mumbai adds different dimensions to the analysis of the empirical data in this thesis.

I am using the concept of domestication to give an insight into how water infrastructure is being taken into Mumbai's middle class homes. The ideas of socio-technical domestication from Shove (2003), Kaika (2004) and Swyngedouw (2004) have informed my socio-technical framing of rainwater harvesting using concepts of political power, control over nature and rescaling of infrastructure, as discussed in the following sections. Domestication is a concept that has relevance across the empirical analysis in this thesis because water infrastructure is rescaled down to the building level by installing rainwater harvesting, as discussed in Chapter Six, and this also controls natural elements and demonstrates power and class status. In turn this leads to a new ways of thinking about housing as a service provider and allows housing to be used as a conduit for governing infrastructure, as discussed in Chapter Five. Following Swyngedouw's (2004) arguments, this means that water provision is even further stratified and the middle class are exerting their power by securing water supplies with rainwater harvesting. I also use domestication to explore how the everyday practices of water use (discussed in Chapter Seven) incorporate, adapt and thus domesticate water infrastructure.

2.3 Urban political ecology

Urban political ecology is a socio-technical concept for looking at the urbanisation of nature and the complex interactions of natural, social, political, technical and economic elements (Greenberg and Park, 1994, Swyngedouw and Heynen, 2003, Swyngedouw et al., 2002). "Political ecology expands ecological concepts to respond to this inclusion of cultural and political activity within an analysis of ecosystems that are significantly but not always entirely socially constructed" (Greenberg and Park, 1994: 1). The interactions between these elements are uneven in distribution and power (Heynen et al., 2006a), and this politicised reading of urban natures informs my later approach to governance. Many scholars have used urban political ecology concepts to frame their investigations of the water infrastructure in specific cities, for example: Swyngedouw (1997, 2004) looks at the politics of water flows in Guayaquil, Ecuador; Kaika (2006) considers droughts in Athens through a political ecology lens; and Loftus (2006) investigates the metabolisms of water in Durban, South Africa. Through the research in this thesis I am adding insights about Mumbai's water infrastructure to this urban political ecology literature.

Urban political ecology is a concept I return to throughout this research and is central to my framing of the water infrastructure in the city of Mumbai and the intervention of rainwater harvesting. There are two aspects of urban political ecology discourse that are introduced in this chapter. Firstly, I discuss how I am using urban political ecology to understand Mumbai's water infrastructure through concepts of metabolism and flow (Gandy, 2004, Gandy, 2008, Heynen et al., 2006b). Metabolisms are central to urban political ecology concepts and aid my understanding of the flows of infrastructure through urban fabric. Secondly, I draw out the political and social aspects of urban political ecology to consider how cities are governed (Forsyth, 2003). This includes the prioritisation of certain initiatives and systems above others as a way to explore environmental injustices in Mumbai (Swyngedouw, 2004).

2.3.1 Understanding Mumbai's water metabolisms

> "… water has become one of the focal points for new attempts to conceptualize the materiality of urban space and the evolving relationship between the human body and urban technological networks." (Gandy, 2004: 365)

Mumbai's municipal corporation does not provide a constant supply and so different sources are carefully managed in the middle class home and this leads the infrastructure to become visible and negotiated on a daily basis (Gandy, 2004, Gandy, 2008). Water tankers (fig. 2.1) are seen on the streets of Mumbai and provide the main source of water for some residents but are also called by the middle classes and elites to top-up their water supply in times of shortage (Graham et al., 2013, Ruet et al., 2002). It is not only the tankers that are reminders of how the water is supplied but also pipes in the streets that are easy to access for maintenance (fig. 3.5) and the various taps in domestic buildings that have to be turned to ensure a constant supply from various sources for different practices (see Section 3.6.2). Thus the metabolism pathways of water flowing through the home are multiple in this differentiated arrangement formed by a combination of small everyday practices (Zérah, 2000).

> "… urban political ecologies expand and insinuate themselves largely "below the radar", through the daily disaggregated practices of hundreds of millions of people, who consume and produce the world around them in the conversion of land, the puddle of wastewater, and the puffing of emission." (Robbins and Sharp, 2006: 111) pg 111

This differentiation of water supply shows the potential for adaptation to deal with climate stresses. Simone (2004) demonstrates the ways in which infrastructure can be differentiated within the urban structure, often using people as more flexible elements. In Mumbai the infrastructure is differentiated in this way to cope with shortages and the heterogeneous nature of infrastructure provision allows flexibility in water supplies for some privileged citizens (Simone, 2004, Zérah, 2000). This is crucial in cities like Mumbai where one centralised supplier cannot cover water demands but it leads to injustice when only certain urban residents have access to multiple water sources, and some citizens have access to none (Swyngedouw and Heynen, 2003).

Water changes as it flows through the city and I am using the lens of metabolism to understand the water flows through Mumbai's infrastructure (Kaika, 2005, Swyngedouw, 2004, Loftus, 2006). Metabolism draws on biological processes as a metaphor for urban infrastructures, and I find this a useful approach that aids understanding the pathways of water infrastructure as few other processes share the level of complexity with the material reality of a city. Metabolisms are various bio-chemical processes: such as the uptake of energy by the human body from food. So just as a slender person is sometimes described as having a 'fast' metabolism, just as a city with well configured and resilient infrastructure might have rapid flows of resources through it (Marvin and Medd, 2006). The composition and meaning of the resource as it moves through the urban environment transforms to become wastes and emissions (Robbins and Sharp, 2006).

Water enters homes in different ways and is metabolized by practices before it flows out as wastewater (Kaika, 2005, Gandy, 2004). This control, storage and use of water for various practices in the home domesticate the water and infrastructure as part of this metabolism. In Kaika's (2005) study of Athens, she suggests that natural elements are not excluded but 'purified' and then allowed into the home. Thus metabolism in the home turns good (clean, useful) 'nature' into bad (dirty, useless) 'nature' (ibid.). For example, clean potable water used to wash the wishes becomes dirty, soapy, contaminated wastewater that is drained away or thrown out. And so this bad nature, this dirty water, is a by-product of the domestic metabolism, but it is discarded and excluded from the home.

Metabolisms are used here to understand how water flows and changes during its journey through the urban landscape and this allows a range of pathways to be viewed in conjunction (Robbins and Sharp, 2006, Heynen et al., 2006a). Metabolism and flow are useful for considering water infrastructure because it goes beyond the static network of pipes to look at the processes that change water. The material networks of pipes and other elements are brought in through the assemblage concepts discussed below. The urban metabolism of water offers a method of unpacking interactions between the social, human and natural elements and the mechanised systems, which must all work together in various combinations (Gandy, 2004). Additionally, it offers a conception of infrastructure that is not predicated upon static built environments and considers change.

Rainwater harvesting is a disruption in the flow of water through the city because water that would otherwise flow out to the sea is diverted into tanks or recharged into the ground water for later use, after which it re-joins the flow. Although the city has already disrupted the flow of rain by forming a concrete barrier over the earth, what I am arguing here is that rainwater harvesting is disrupting the normalised flow of water through Mumbai (Gandy, 2008). It mitigates some of the issues arising from other pathways and gives the residents some ability to cope with the unpredictable water supply (Zérah, 2000).

2.3.2 Governing and urban political ecology

The political emphasis of urban political ecology means that it is linked to issues of power and how cities are governed (Bulkeley et al., 2013, Bulkeley and Betsill, 2003). The governance of the water infrastructure and the ways in which crises are managed highlight issues for environmental debates (Bulkeley and Betsill, 2003, Bakker, 2010). Thus the move from natural phenomenon of drought though the creation of water as an economic commodity to the social construct of water shortage is central to the ways in which water infrastructure is governed (Bakker, 2010, Smith and Ruiters, 2006, Kaika, 2006):

> "Water is being revalued and re-presented as a scarce economic good. With this shift, the triangular relationships between external provider, the state and the citizen - the three critical agents in the delivery of water - take on new forms with the ascent of the neo-liberal paradigm." (Smith and Ruiters, 2006: 191)

The privatisation of water supply is prominent in the urban political ecology literature regarding governance and power (see Bakker, 2003b, Kaika, 2005, Swyngedouw, 2004). Smith and Ruiters (2006) see the control of the state being expanded by the extension of infrastructure provision in South Africa, also see de Certeau (1984), but this contrasts with the situation in Mumbai where the slums are denied infrastructure in order to control the population with a view redevelopment (Das, 2003, Graham et al., 2013). The water infrastructure is highly differentiated in Mumbai, due to shortages and personal choice of provision, and this leads to water being controlled by an enmeshed network of public and private actors (Gandy, 2008, Anand, 2011). Mumbai's water system is public and yet some members of society have no access to piped state water at all and so have to purchase water from private vendors (Graham et al., 2013, McFarlane, 2008b, Ruet et al., 2002). In Chapter Five of this thesis I discuss a novel form of water supply privatisation in Mumbai that puts housing at its centre. The complicated and differentiated supply, and therefore governance, of water in Mumbai adds different dimensions to my analysis of rainwater harvesting.

These interaction of urban infrastructure are further illuminated by theories of splintering urbanism, which views cities as a series of socio-technical processes that are being separated from each other (Graham and Marvin, 2001, Courtard, 2008, Zérah, 2008). Graham and Marvin (2001) examine the relationship between cities and their networks to consider the contemporary urban condition as these complex infrastructures are dissolved into disparate parts. Political actors are shaping urban infrastructure provision changes and neo-liberal policies have accelerated the splitting up of networks as privatisation and markets take hold worldwide (Bulkeley et al., 2013, Graham and Marvin, 2001, Zérah, 2008, McFarlane and Rutherford, 2008). The unbundling of systems is a useful way to consider and unpack the infrastructure, but the infrastructure in Mumbai is largely unpacked already. Zérah (2008) looks at Mumbai through the lens of splintering urbanism and finds the city's networks to be highly fragmented and that Mumbai's infrastructure provision was fractured from the beginning. In Mumbai there is an expression of desire by the municipality and citizens to integrate, or 'bundle', the water infrastructure but this competes with large private companies who seek to privatize the water system (Zérah, 2008).

The costs and benefits of environmental change are unevenly distributed, with the poor who have low impact on the environment often being the ones most affected by extreme events and gradual changes, as they do not have the resources to build resilience (Satterthwaite et al., 2007, Dodman and Satterthwaite, 2008). These inequalities are evident at the urban scale and are particularly pertinent to this exploration of governance in Mumbai as the requirements of the influential middle classes are put above the needs of the poorer residents of the city (Mawdsley, 2004, Baviskar, 2011). These inequalities further reinforce social and economic differences and those who are excluded from the technological networks and services are also excluded from certain parts of society (Kaika and Swyngedouw, 2000). This is important at several spatial scales including the North-South divide and within each city leading to power struggles, exclusion and segregation.

I use urban political ecology in this research as a useful way to conceptualise Mumbai's infrastructure as a socio-technical process at the urban scale drawing on metabolism concepts from Gandy (2004), Kaika (2005, 2006), and Swyngedouw (2006). The political nature of infrastructure provision has informed my framing of how Mumbai is governed (Kaika, 2006, Swyngedouw and Heynen, 2003). However to focus down on one system and specific dwellings I turn to assemblages.

2.4 Assemblage

Rainwater harvesting has many configurations comprising of a multitude of different elements. I use aspects of assemblage theory to conceptualise the process of designing, installing and maintaining rainwater harvesting systems in Chapter Six. I also use assemblage to inform my understanding of governance through uneven power distribution and the inclusion of legislation in Chapter Five, and to understand water-use practices in domestic buildings in Chapter Seven. Assemblage is used as a way to focus in the urban political ecology concepts to concentrate on the flows and disruptions in one system. Within the broad spectrum of assemblage theories, I find the concept of assembl*ing* to be most useful in understanding the empirical data.

In this section, firstly, I introduce assemblages as formed of material and discursive elements to create something that is more than the sum of its parts. Secondly, I discuss the embedding and stabilisation of the assemblage as 'territorialisation'. Thirdly, I explain the assemblage as practice based and always changing through processes of dis- and re-assembling, translation, and tinkering. I use these concepts to understand rainwater harvesting as a process and especially how the different elements are drawn together and embedded within buildings.

2.4.1 Heterogeneous components

An assemblage approach considers the various heterogeneous elements drawn into a process (for example: politicians, pipes, diagrams, laws, mosquitoes and water). An assemblage cannot be explained by or reduced to its component parts and informs us about the relationship between parts and the whole (Bennett, 2005, McCann, 2011). The parts have meaning as separate entities but function together as a dynamic assemblage with emergent properties (Bennett, 2005, De Landa, 2006). The concept of the assemblage is thus a tool for interpreting the multiple configurations of infrastructure in a city and everyday practices (McFarlane, 2011). The analysis of infrastructure in Mumbai is further complicated by people performing integral tasks, such as delivering water, as part of the infrastructure assemblage, as explained in Section 3.6 (see Simone, 2004, Graham et al., 2013).

Some elements may not be wanted within an assemblage and can be excluded through design or later changes. I draw the concept of exclusion from de Laet and Mol (2000) in which they discuss bush pumps for accessing water in Zimbabwe. De Laet and Mol's ideas concerning design and maintenance are drawn from an Actor Network Theory reading of the system. In de Laet and Mol's (2000) interrogation of the bush pump in Zimbabwe, they discovered design changes to exclude unwanted elements. In particular, the surround of the pump was designed and assembled carefully to exclude contamination with *E-coli*, which demonstrates the agency of the unwanted elements (de Laet and Mol, 2000). From this starting point, I use the concept of exclusion in Chapter Six to understand how unwanted elements shape the design, construction and maintenance of rainwater harvesting assemblages.

The components of an assemblage are material and/or discursive and each adds to the emergent properties of the assemblage (McFarlane, 2011). The networking of material and discursive elements in water infrastructure is also noted in urban political ecologies but assemblage allows deeper interrogation of this relationship (Swyngedouw and Heynen, 2003). An element can be both material and discursive, performing dual roles within an assemblage (De Landa, 2006). Translation of an element from material to discursive properties can shift the assemblage in that direction, and can be used in the governance of infrastructure (McFarlane, 2008a). This concept of translation is discussed in the next section as one of the types of change experienced by an assemblage.

2.4.2 Change: dis-assembly, re-assembly, translation and tinkering

Assemblages are dynamic and ever-changing (McCann, 2011, De Landa, 2006). This section answers the question: how can assemblage approach explain change within systems? Three modes of change in assemblages are identified: disassembly and re-assembly; translation; and tinkering.

Assemblages are often uneven in their power distribution between components and decentre human agency. This unevenness leads to instability and constant processes of dis-assembling and re-assembling (McFarlane, 2011, McCann, 2011). The stability of an assemblage can be defined as territorialisation, when the assemblage claims a certain space or set of artefacts and, conversely, de-territorialisation indicates instability or a state of change (McCann, 2011). Territorialisation does not necessarily refer to the spatial aspects, or territory, of the assemblage and can also be taken as a measure of the homogeneity of elements (De Landa, 2006, McCann, 2011). These terms of territorialisation are taken from Deleuze and Guattari (1994) but *stability* of the assemblage is a more appropriate term for use here. However, it should be note that an assemblage is constantly changing rather than a static network, and stability may not be the goal (McFarlane, 2011, De Landa, 2006). Although an assemblage is always in flux, there are moments of relative stability.

The changing of one part of the assemblage during these processes of dis- and re-assembly can cause changes throughout, which can be a creative and innovative process (Farías and Bender, 2010). However these changes could make the assemblage obsolete if the emergent properties change or a major component is removed (de Laet and Mol, 2000). For example if a rainwater harvesting system changed so that is no longer performed that function, it would be obsolete, unless reconfigured to provide some other service.

Translation of elements relates to their state and a component's role in an assemblage can be altered by translation when the component takes on another meaning or property (McFarlane, 2011). Translation is also used to demote progressive change during a socio-technical transition as innovation takes place (Berkhout et al., 2010). Processes of translation occur from material components to discursive components as 'inscriptions' (McFarlane, 2011). These could be systems drawings or publicity materials, which can then be used to shift the boundaries of the assemblage and potentially draw in more elements. Discursive elements formed through translation can be used to control and govern infrastructure, for example: by the translation of ideas and material artefacts into legislation (McFarlane, 2008a, Graham et al., 2013).

Assemblages also change in smaller ways. Graham and Thrift (2007) and McFarlane (2011) see this tinkering taking places as dwellings are constantly changed and improved by residents. In Mumbai the self-assembly of buildings does not just applying to the auto-constructed dwellings in informal settlements but also to the middle class housing that is gradually reshaped to fit the residents' needs. Middle class housing in Mumbai is constantly adapted in small ways, or tinkered with, though maintenance and additions of systems:

> "While many urban buildings, especially in the global South, are auto-constructed and continually adapted – even architecturally designed buildings are constantly being tinkered with. This produces gradual but distinctive changes in their layout, skin and appearance. Very often, the issues raised by this continual repair and adaptation of buildings are actually completely ignored in the original design process." (Graham and Thrift, 2007: 6)

The concept of 'tinkering' is also taken up by Anne-Marie Mol (2010) to consider how small incremental changes alter a system. "As technologies and techniques are being tinkered with, they are fluidly adapted" (Mol, 2010: 265). This tinkering is part of the fluctuating existence of the assemblage and can also be a form of maintenance particularly applicable in the Global South where objects are still repaired and reused. Maintenance is a key part of innovation as material systems are adjusted in small ways and remodelled, to solve problems and to fit the local needs and availability of resources (de Laet and Mol, 2000, Graham and Thrift, 2007). The concept of tinkering could imply the role of the 'tinkerer' who stands outside the network, but using assemblage concepts the tinkerer is drawn in as a component of the assemblage.

The small adjustments, by all the mechanisms considered here, can add to the resilience of systems and also to innovation (Graham and Thrift, 2007). Assemblage approaches change through processes of disassembly, re-assembly, translation and tinkering (McFarlane, 2011). However these concepts do not have the directional focus of large-scale change and so in Chapter Six I combine these ideas with concepts of socio-technical transitions to address changes caused by rainwater harvesting in Mumbai.

2.5 Responses to environmental change in the Global South

> "Most people writing on urban environmental and ecological issues, particularly in Asia, Africa and Latin America, agree on the importance of both addressing environmental issues and reducing poverty." (Haughton and McGranahan, 2006: 3).

Environmental issues need to be addressed in a number of ways and at different scales, whilst also continuing development (Bulkeley and Betsill, 2003). I have conceptualised cities and infrastructure as being socio-technical and inseparable from nature. It is therefore unsurprising that many scholars use socio-technical concepts to investigate the effects of the environment on cities (Gandy, 2006a, Kaika and Swyngedouw, 2000, Swyngedouw, 2004) and urban responses to climate change (Guy and

Shove, 2000, Lovell, 2007, Berkhout et al., 2010, Bulkeley et al., 2013). I use socio-technical concepts to analyse how rainwater harvesting is being used respond to water shortage and environmental stress. In this section I firstly explain the environmental and climate change vulnerabilities of urban areas in the Global South, and this discussion is later taken up at the beginning of Chapter Three to set the context of Mumbai. Secondly, I discuss the different responses to environmental vulnerabilities focusing particularly on housing and infrastructural responses.

2.5.1 Environmental vulnerabilities

Asia, Africa and South America are predicted to experience more precipitation leading to floods, more droughts, an increase in extreme weather events (particularly cyclones), and rising sea levels that will also affect fresh water supplies (Moser and Satterthwaite, 2008, Revi, 2008, Ranger et al., 2011). Mumbai is at risk from all these factors that could lead to more flooding from precipitation and sea-level rise, as well as droughts (Ranger et al., 2011, Revi, 2008, Timmerman and White, 1997). Climate change is already affecting many parts of the world and the Global South, including Mumbai, is to be disproportionately affected by climate change (UN-HABITAT, 2011, Stern, 2006, The World Bank, 2010). The majority of the emissions leading to climate change originate from the Global North or 'industrialised nations' but the extreme changes to weather are predicted to occur in the Global South, where populations are least resilient and the infrastructure is inadequate (Dodman and Satterthwaite, 2008).

The nexus between urban poverty and climate change vulnerability has rightly been prevalent in academic debates and linked to the goal of tackling environmental problems without stopping development (World Commission on Environment and Development, 1987, Satterthwaite et al., 2007, Dodman and Satterthwaite, 2008, Ahammad, 2011, Ensor and Berger, 2009). The urban poor in low- and middle-income nations are affected most severely by climate change because cities in the Global South have generally have dense populations, poorly constructed housing and inadequate infrastructure (Satterthwaite et al., 2007, Tanner et al., 2009). The prevalence of informal settlements, built in marginal areas from reclaimed materials, makes the urban poor in Asian cities especially vulnerable (Adelekan, 2010, Davis, 2004). Middle class residents are often excluded from the picture by the important focus on the most vulnerable communities but this can lead to a partial view of the situation (Lemanski and Lama-Rewal, 2013). This thesis adds to the under-researched nexus of the Indian middle classes, the environment and infrastructure.

2.5.2 Responses to environmental change

There are two classes of response to climate change: adaptation and mitigation. In this section I firstly introduce adaptation, which is the response largely associated with rural Global South and is a reaction to changes and events. Secondly I discuss mitigation, which is the response mostly seen in urban areas of the Global North and the focus of most international negotiations on climate change to reduce the causes of climate change. Thirdly I explain that, although often discussed separately, adaptation and mitigation are interlinked concepts and rainwater harvesting is an example at the nexus of them (Klein et al., 2007, Pandey et al., 2003).

2.5.2.1 Adaptation

Adaptation is the preventative actions undertaken to reduce the effects of climate change and is linked to the building of resilience (Ensor and Berger, 2009). Adaptation is carried out through initiatives such as improved infrastructure, insurance, behaviour change and early warning systems. Focus has until recently been on rural responses in the Global South, but urban areas have gained attention as rapid urbanisation has led to many poorly constructed dwellings with inadequate infrastructure being built on unsuitable land (Datta, 2012, Ahammad, 2011, Davis, 2004). The vulnerability of poor urban communities, who have had little negative impact on the environment, makes this an important environmental justice issue (Dodman and Satterthwaite, 2008, Wamsler, 2007).

There are two levels at which adaptation strategies are implemented – the government-led ('top-down') approach and the community-led, often with NGO support, ('bottom-up') approach (Larsen and Gunnarsson-Östling, 2009, Bulkeley et al., 2011, Dodman and Satterthwaite, 2008). This means that infrastructural adaptation can be large-scale interventions, such as flood defences, or local initiatives, such as changing roofing systems to cope with heavier rain (Button et al., 2013). However, Satterthwaite *et al* (2007) are concerned that 'adaptation' is inappropriate in situations where there is no infrastructure to be adapted in the first place. A lack of infrastructure can also hamper the responses to extreme weather events and disasters. This disjunction creates a policy agenda at a level far removed from the local realities and again brings into question the direct transferability of concepts. Where response to climate change is considered in cities of the Global South it is framed in terms of technology transfer, but technologies must be appropriate for the location and thus it may not be the optimum strategy. The way buildings are designed demonstrates the differences:

> "Many developing countries look to the west as a model but that cannot be the model. These [western] buildings use too much power and would not be affordable for us." Jockin Arputham, founder of the National Slum Dwellers Federation of India (quoted in Booth, 2009)

Constructing more resilient housing systems in the Global South is well established as an adaptation to climate change and flood resistant housing has been constructed in response to heavy rain and rising sea levels in Asia. These include initiatives led by the NGO *Practical Action* (Practical Action, 2009) and housing to resist flooding and typhoons in Vietnam (Building and Social Housing Foundatiion, 2009).

2.5.2.2 Mitigation

Climate change mitigation is the reduction of the cause of anthropogenic climate change: greenhouse gas (GHG) emissions. As well as being a major contributor to the problem, cities are vital to the response and their high population densities could be utilised to great effect for the mitigation agenda (Rees and Wackernagel, 1996, Dodman, 2009, Fragkias and Boone, 2013). Mitigation strategies are epitomised by international negotiations and emissions targets, which are most effective when co-ordinated at all levels and involve local communities (Bulkeley and Betsill, 2005, Klein et al., 2007, Bulkeley et al., 2011, Larsen and Gunnarsson-Östling, 2009, Lee, 2006, Crabtree, 2006). Concepts that are often of little concern to local politicians, such as climate change, are framed as local issues addressed with local policies to mitigate climate change (Betsill, 2000). Local governments can have wide reaching effects and their experiments can become national policies, as demonstrated by Freiburg in Germany and Sorsogon in The Philippines (Schreurs, 2008, Button et al., 2013). This could lead to South-South transfer of appropriate technologies (Lankao, 2007, Zhou and Lin, 2003, Spivak, 1988).

The construction industry contributes heavily to global GHG emissions through the creation of materials and energy consumption during building. The domestic consumption of energy after construction also increases emissions making housing a popular environmental intervention, especially in the Global North where binding emissions reduction targets are reinforced by legislation such as the United Kingdom 's *Zero Carbon Homes* initiative, which aims for all new homes to be 'zero carbon' by 2016 (UK Greenhouse Gas Statistics & Inventory Team, 2013, Communities and Local Government, 2009b). Considering issues such as local air quality and resource conservation makes a strong case for the mitigation of climate change through the development of housing systems in the Global South, and critiques the popularity of globalised architectural styles that do not reflect context or climate.

The Global North has an important role in mitigation and should bear the responsibility of mitigating (Satterthwaite, 2008, Stern, 2006). However the potential of cities like Mumbai to mitigate climate change should not be overlooked (CAEP-TERI, 2011, Revi, 2008). These cities have the opportunity to develop sustainably, and 'leap frog' to more advanced infrastructure, if the political will and funding are in place (Goldemberg, 1998, Revi, 2008) and environmental technologies and innovative infrastructure should not be positioned as secondary to centralised infrastructure (Bakker, 2010). Mitigation of climate change in the Global South is a contentious issue as it is sometimes seen as being a distraction from both more urgent adaptation and important development goals (Moser and Satterthwaite, 2008). However, mitigation provides a long-term view that aims to decrease the severity of future changes and fragmented cities of the Global South have an opportunity to act and create innovative pathways towards climate resilience. Each city has different vulnerabilities, governance and infrastructure and so urban responses should be appropriate to the context (Bai, 2007).

2.5.2.3 Bringing adaptation and mitigation together

Responses to environmental vulnerabilities and change in the Global South have focussed on adaptation, especially to extreme events in rural areas (Practical Action, 2009). Whereas interventions in the Global North have focussed on mitigation because as Heinrichs *et al* (2011) suggest, although adaptation is important, that agenda has not been pushed due to concerns over distracting from mitigation as a priority, especially in international negotiations. Both mitigation and adaptation are implemented at a range of scales by federal regional and local government departments but they may have more potential for integration than is currently being achieved and policy implementation in one area has an effect upon the other (Klein et al., 2007, Larsen and Gunnarsson-Östling, 2009). This is a process being encouraged by the Inter-governmental Panel on Climate Change's (IPCC) which devotes a chapter to the interrelationships between the strategies in its 4th Report (Klein et al., 2007).

Adaptation and mitigation are closely linked and can be used together within policy to effectively address climate change and environmental vulnerabilities in urban areas (Button et al., 2013, Larsen and Gunnarsson-Östling, 2009, Klein et al., 2007). Rainwater harvesting is a technology that addresses both mitigation and adaptation. It mitigates climate change by reducing the treatment and transportation of water and also helps the adaptation to climate change by building resilience to drought and reducing localised flooding (Handia et al., 2003, Pandey et al., 2003, Municpal Corporation of Greater Mumbai, 2003). The provision of alternative water sources, such as rainwater harvesting, for the middle classes has the potential to make more water available for the poorer residents but, as discussed in Chapter Seven of this thesis, this may not always happen in reality.

2.6 Socio-technical framing of rainwater harvesting

Society and technology are interdependent, and this relationship between material and culture frames the socio-technical approach (Anderson and Tolia-Kelly, 2004, Gandy, 2005, Latham and McCormack, 2004). This co-production and interrelationship between heterogeneous aspects informs debates in urban geography. "The older categories of the city (i.e. the social, the political, the cultural, the separation of humans and machines) have all been subject to strain and transformation..." (Sundaram, 2010: 7). Socio-technical concepts allow all these elements of a city to be considered simultaneously and to analyse the interactions between them. This chapter has introduced the socio-technical concepts that I employ to analyse the empirical data to investigate the domestication of infrastructure. I have not aspired to create a meta-theory but have constructed a tool-kit of concepts for interpreting the empirical findings, which will be added to within later chapters to address weaknesses in the approaches.

A socio-technical approach to address climate change in the Global South has not been widely used (noteable exceptions are Lankao, 2010, Berkhout et al., 2010). This reluctance to engage with socio-technical framing of responses in the Global South may spring from the focus on the urban poor, and the characterisation of Asian cities as a dichotomy between poor and elites (Lemanski and Lama-Rewal, 2013). Lee (2006) argues that classical environmentalism is not effective because poor cities are vulnerable to climate change but do not have the capacity to act, whereas rich (OECD) cities do not have the inclination or incentives of risk (Haughton and McGranahan, 2006). This applies at smaller scales, such as within a city where the rich can buy their way out of the issues and the poor have low resilience, and thus the growing middle classes are central to the urban response in the Global South (Swyngedouw and Heynen, 2003). Applying a socio-technical reading of environmental infrastructure initiatives in the Global South enriches understandings of how interactions between human and non-human actants are mediated and enacted. Thus I use these socio-technical approaches to unpack the middle class homes in Mumbai as sites for responses to water shortage exacerbated by climate change.

In this chapter I have considered two key socio-technical concepts that are used in this thesis to look at different scales of urban water infrastructure: urban political ecologies and assemblages. These concepts are used in a purposeful way to unpack different aspects of the empirical data but there are also crucial links and overlaps. Urban political ecology is used in this thesis as a way of interpreting the city as formed of social and technical aspects and the uneven distribution of resources and power inform my understanding of governance and justice issues, which are particularly pertinent to infrastructural flows in the Global South. Water is changed through processes of metabolism as it flows through the city and these changes are inherently political and shaped by various actors (Heynen et al., 2006a). An assemblage approach allows me to focus on one system and explore the flows, interrelationships and processes within. The concepts of change presented by assemblage theory are useful in this research for engaging with the changes in the rainwater harvesting systems as they are installed, used and maintained through processes of dis-assembly and re-assembly, translation, and tinkering (McFarlane, 2011). These are useful approaches for understanding the unplanned responses to water shortage that occur through everyday practices in the Global South, but do not address purposeful, directional change.

Applying concepts developed in the Global North to situations in the Global South can be problematic (Robinson, 2006). And scholars have been tentative in using a socio-technical perspective in the Global South, but I have argued in this chapter that it could provide insights into infrastructure provision. Urban political ecology concepts inform the approach to governance taken in Chapter Five, and develop my understanding of flows through Mumbai. Assemblage is used in the conceptualisation of rainwater harvesting systems in Chapter Six, in particular to analyse the ways in which they are designed, installed and maintained. Chapter Seven combines these two socio-technical approaches by considering the practices of water use through an assemblage lens, combined with the metabolism of water through the buildings and discussion of inequalities.

Chapter Three

Mumbai, middle class housing and rainwater harvesting

Figure 3.1 Mumbai's Housing (Source: Author)

3.1 Introduction

Mumbai is a complex city that is richly chronicled in literature and film, and often presented as a dual city of slums in crisis and isolated luxury towers (Patel, 2003, Pacione, 2006). At first glance fig. 3.1 on the cover page of this chapter reinforces this dichotomy but closer inspection reveals the smaller blocks in between and a huge variety of housing types. It is those residents that sit between the urban poor majority and small group of elites that I am investigating in this research. Lemanski and Lama-Rewal (2013) identify the middle classes as 'missing' from academic and policy debates in Delhi. Discussions of urban India have been simplified by ignoring the middle classes to create a perceived polarisation of the population and this thesis adds to the renewed interest in replacing the 'missing middle' into academic debates (Fernandes, 2006, Mawdsley, 2004, Lemanski and Lama-Rewal, 2013, Brosius, 2010). I see Mumbai as a multiple city, rather than a simple duality, with areas and services visible and accessible to different people, so that every individual's experience and imaginary of the urban space is different.

I chose Greater Mumbai as the case study city because of its complexities, and particularly its housing and water issues in conjunction with rapidly growing middle classes. Mumbai's water supply is particularly uneven in its distribution (see section 3.6) and shortages are pushing rainwater harvesting up the agenda as urbanisation and risks from environmental changes (including altering weather patterns and sea-level rise) increase vulnerability to further water shortages (Ranger et al., 2011, Nicholls et al., 2008, Revi, 2008).

In this chapter I aim to introduce the aspects of Mumbai that are pertinent to the specific research questions and site the empirical work explored in the following chapters. It is not my intention to give a broad overview of the city or detail its history here, rather this background and context chapter sets the scene for the empirical heart of the thesis formed by several interlocking areas: Firstly, I introduce Mumbai's location and climate, and discuss how climate change stands to affect the city, with water being the most pressing issue. Secondly, I briefly lay out the international and national response to climate change from India before focusing on the local government agencies and policy structure of Mumbai as regards the environment, water and housing. Thirdly, I discuss India's middle classes including the difficulties defining this homogeneous and broad community. Fourthly, I introduce the housing context in Mumbai, which in some ways defines the city through its complexity and failings, and position this research within middle class housing. Finally, I lay out Mumbai's water infrastructure to describe how the middle classes have a plentiful domestic water supply and how rainwater harvesting can fit into this system of water provision.

3.2 Mumbai

Mumbai is a mega city located on the west coast of India and stands on a peninsular that was originally seven islands, which were made into one landmass during the 19th century (Municipal Corporation of Greater Mumbai (MCGM), 2007, Patel and Masselos, 2003). This peninsular location (see fig. 3.2) has limited Mumbai's opportunities to sprawl and has contributed to the high population density and raised land prices. Bombay, later renamed Mumbai, was developed as a major international trading port by the British and flourished with the cotton industry (Patel and Masselos, 2003). Many old cotton mill chimneys are still standing but most of the mills have been recently developed into housing, offices or shopping malls, following the relaxation of development regulations. Although the cotton industry declined, Mumbai still has a thriving manufacturing industry, both in formal and informal sectors, putting the city at the heart of India's thriving economy as the biggest contributor to gross domestic product (GDP) (Mehta, 2005). Mumbai is now the economic capital of India and houses India's stock market. Mumbai's history and location have led it to become a very cosmopolitan place that is a global networked city. The municipality want to build on this high profile to make Mumbai a world city (Municipal Corporation of Greater Mumbai (MCGM), 2007). To reach this aim the MCGM have acknowledged that the water system inadequacies and housing problems need to be addressed, and that they also need to consider environmental issues to improve their position in relation to other cities on the world stage (*ibid.*).

3.2.1 Mumbai's changing climate

India has six climatic zones and Mumbai sits within the large tropical-wet zone (De Sherbinin et al., 2007). This means that Mumbai has a hot humid summer followed by heavy monsoonal rainfall from June to September. Mumbai is expected to have a tropical cyclone (hurricane) about once a year. However, the weather patterns are becoming more unpredictable with more frequent floods, droughts and cyclones (Revi, 2008, Nicholls et al., 2008). Mumbai's location on the west coast of India, and peninsular formation (as shown in fig. 3.2) constructed of low-lying reclaimed land (see fig. 1.1), leaves it particularly vulnerable to sea level rise predicted due to climate change (Tanner et al., 2009, Ahammad, 2011, Boyd et al., 2009). Mumbai has the population most exposed to climate change of any port city in the world and conditions are not predicted to improve (Nicholls et al., 2008).

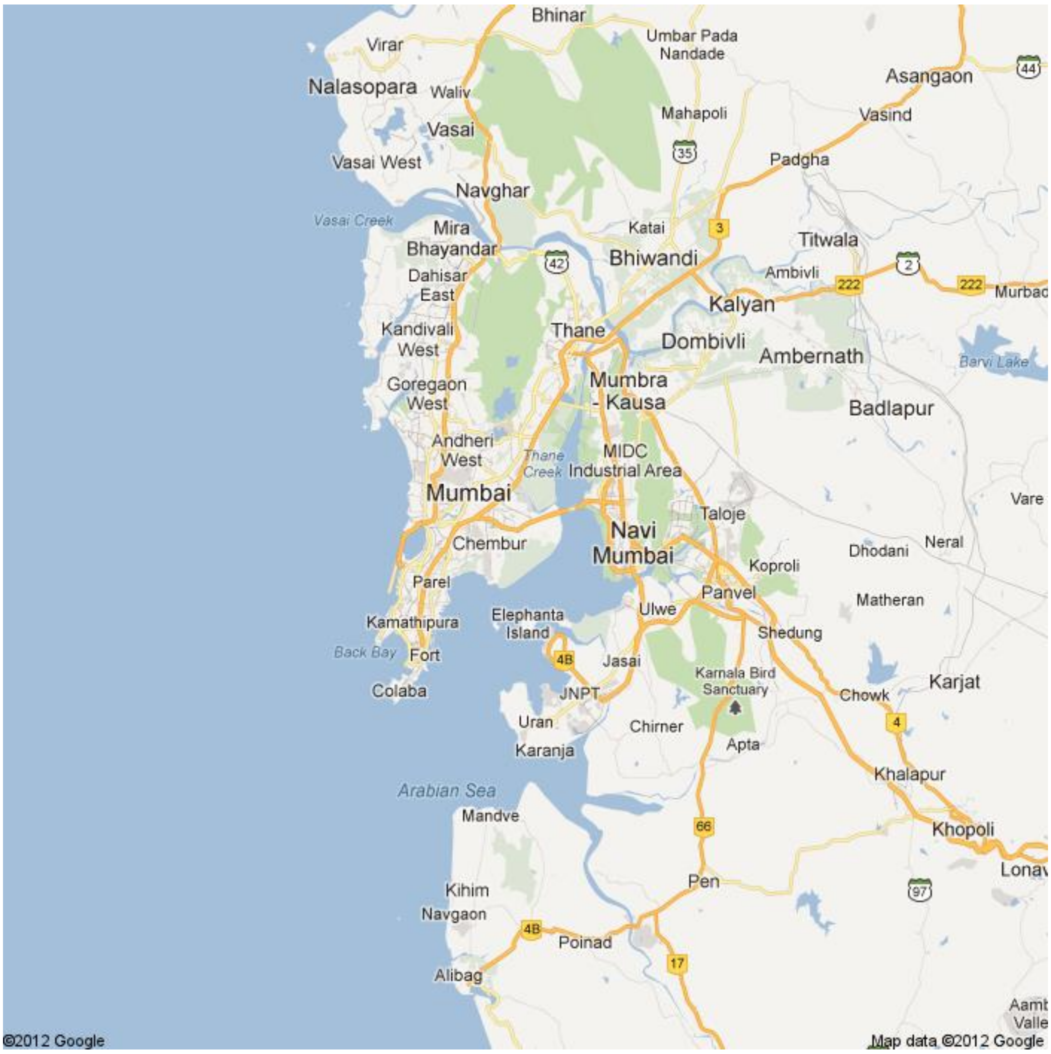

Figure 3.2: Map of Mumbai (Source: googlemaps)

The predicted change in sea levels will greatly affect coastal cities, especially these unprotected ones on Asian coasts (Yeung, 2001, Timmerman and White, 1997). Floods and inundations are common during the monsoon season, sometimes increased by cyclones (De Sherbinin et al., 2007). However, the flood of 2005 was an unprecedented event that caused huge property and economic damage and the loss of an estimated 500-1000 lives (Ranger et al., 2011, Prakash, 2008, Concerned Citizens' Commission, 2006). It was a one in a hundred year weather event that demonstrated how vulnerable Mumbai is and triggered a rethink of disaster response by the municipality (Bulkeley et al., 2011, Concerned Citizens' Commission, 2006).

3.2.2 Infrastructure vulnerabilities

Revi (2008) uses the example of the 2005 flood to explore vulnerabilities of Mumbai's infrastructure to extreme weather events. The floods shut down most city services, cut Mumbai off from the rest of the country and killed many people (Revi, 2008, Concerned Citizens' Commission, 2006). The lack of preparation for such events is highlighted along with vulnerable infrastructures and residents. The floods have been blamed on a variety of factors including: blocked, unmaintained and inadequate drains: the mismanagement of urbanisation; concretisation reducing absorption; and the construction of the Bandra-Kurla Complex blocking some outflows (Concerned Citizens' Commission, 2006, Gandy et al., 2007, Municipal Corporation of Greater Mumbai (MCGM), 2007, Municipal Corporation of Greater Mumbai (MCGM), 2013).

As the climate changes these events are likely to increase in frequency. Temperatures are also predicted to rise and this is likely to increase energy consumption as more electricity is used for air-conditioning and fans by the middle and upper classes to maintain comfort levels (Shove, 2003a). This will put further strain on the electricity infrastructure of Mumbai, leading to shortages. Water shortages are already experienced, as discussed in Section 3.6, and these inadequacies lead to further vulnerability:

> "The city also cannot undertake large-scale repairs of trunk mains because there are no alternative water distribution tunnels available to temporarily divert water and avoid extensive disruption so that minor problems can easily escalate into catastrophic system failures." (Gandy, 2006b: 19)

Minor problems and leakages are having an impact and maintenance and improvement of the water infrastructure us now a pressing concern (Municipal Corporation of Greater Mumbai (MCGM), 2007). Water is a key infrastructure to secure because all people need water. If an issue, such as water shortage, affects all citizens, including the elites and middle classes then government, as well as institutions and individuals, are more likely to take action (Swyngedouw, 2004, Harvey, 1996). The elites and middle classes are able to prioritise problems that affect them and promote solutions that benefit them, often at the expense of poorer citizens (Véron, 2006, Williams and Mawdsley, 2005). This is seen in Delhi where the right to a clean environment was used to push through legislation on the conversion of vehicles to compressed natural gas mainly at the cost of poor auto-rickshaw drivers (Baviskar, 2011, Véron, 2006). This demonstrated the justice issues that arise from the framing and subsequent solution to issues in urban India, and this is explored further in Chapter Five. Mumbai's water supply is in need of improvements and extension, or other sources to be found to increase resilience of the system. Inaction on universal water supply, housing and other issues of the poorer residents of Mumbai can be seen as arising from a distancing of the issues from government officials and a lack of agency on behalf of the poorer citizens.

3.3 Government and administration

Environmental policies that affect Mumbai have been implemented at three levels: the international, national and local. Administrative processes in India are renowned for being heavily steeped in bureaucracy and corruption, which further complicates the narrative. In this section I firstly introduce India's stance in global negotiations. Secondly I discuss the policies at national level that impact on responses in Mumbai. Thirdly, I lay out the administrative structure of Mumbai and introduce the legislation that influences the environment, water infrastructure and housing.

3.3.1 India's international stance on climate change

India is one of the most powerful nations in the world and there is a move by members of the G8 to expand to include five emerging economies, including India, (these five are called Outreach 5 or Plus 5), demonstrating their importance on the world stage (G8, 2009). India has an important place in global climate change negotiations due to its international political power combined with high emissions (Fisher, in press). India's large population (over one billion) leads it to become one of the biggest emitters of GHGs. In 2010 India disclosed its carbon emissions from the first time since 1994, which was part of a change in international stance on climate change (Watts, 2010). The emissions have jumped in the twelve years between announcements largely because of industrialisation. India's stance on climate change mitigation has been consistent for several years in rejecting any binding targets for emission reductions from developing countries. However, the Minister for Environment and Forests moved from this position for the first time in 2010 (Fisher, in press). This change in international stance drew criticism from other Indian politicians; however it is in line with domestic initiatives that had already been rolled out.

In contrast to the high country-level GHG emissions, per capita emissions in India are still low by global standards (1.7 tonnes), because the majority of the rural and poor urban population have negligible emissions (The World Bank, 2010, Moser and Satterthwaite, 2008, Fisher, in press). Thus I would argue that the urban elites and middle classes have become global citizens and are consuming energy and emitting carbon at relatively high levels.

International networks are another way of interacting on the global stage and disrupt the neatness of scales of response. Mumbai is a world city, highly connected to other cities and part of global networks, linking knowledge sharing and commerce activities and creating opportunities for sharing ideas (Banerjee-Guha, 2007, Hodson and Marvin, 2012, Nijman, 2007). Mumbai has joined the C40 cities group (Large Cities Climate Change Leadership Group) run by the Clinton Foundation (Clinton Climate Initiative, 2008). The scheme promotes best practice in a range of areas, including housing. Cities appoint themselves into the C40 group, but there is little evidence of involvement on the ground. Mumbai is also a member of ICLEI (Local Governments for Sustainability), which is a voluntary scheme and is based on *Local Agenda 21* (ICLEI, 2008). The ICLEI scheme attempts to be a knowledge network between cities but is limited in its success (Betsill and Bulkeley, 2004). Whether or not these initiatives are making a difference is, I would argue, not as important as the fact that the Mumbai municipality joined them. This demonstrates aspirations (and actions) towards environmental ideas as part of placing Mumbai as a world city.

3.3.2 National policies

The Ministry of Environment and Forests has traditionally been responsible for environmental policies in India since independence in 1947. However, as climate change rises up the political agenda, the Ministry of New and Renewable Energy (MNRE) has grown in importance, and the other energy ministries and the Ministry of Science and Technology have taken a more proactive approach (Fisher, in press). The National Disaster Management Authority is also involved in responding to and mitigating against extreme weather events (Revi, 2008). This has led to a piecemeal approach to environmental policy, with much of the responsibility and power devolved to the state level. One key policy that has affected Mumbai is the Coastal Regulation Zones.

Coastal Regulation Zones (CRZ) is a policy that aims to protect coastal wildlife and in Mumbai should help to stop destruction of the delicate mangrove eco-system by preventing development near the coast (Das, 2003). This has been used to justify the removal of informal settlements. It also causes problems in the peninsular South Mumbai to re-developments of built up areas that are on man-made land, and has led to planning appeals.

3.3.3 Mumbai (and Maharashtra)

Mumbai's local government agencies are complicated and intertwined as acknowledged by the municipality themselves (Municipal Corporation of Greater Mumbai (MCGM), 2007). A multi-level view can be effective for describing international and national governance landscape (see UN ESCAP Country paper on India) but when focussing down to the urban level the actors are enmeshed.

> "Current legal, regulatory and governance structures and the institutional culture of most cities are inadequate to address the challenge of climate change adaptation and mitigation." (Revi, 2008: 222)

The Government of Maharashtra was forward thinking in 1990 and drew up an urban disaster plan pointing to flooding as a risk and the bottleneck that would increase vulnerabilities (Revi, 2008). However, nothing was implemented and so the 2005 floods were a stark reminder of these vulnerabilities. The lack of action could be due to the complicated nature of local government in Mumbai. Fig. 3.3 illustrates the different actors within Mumbai's government and municipality and their broad responsibilities.

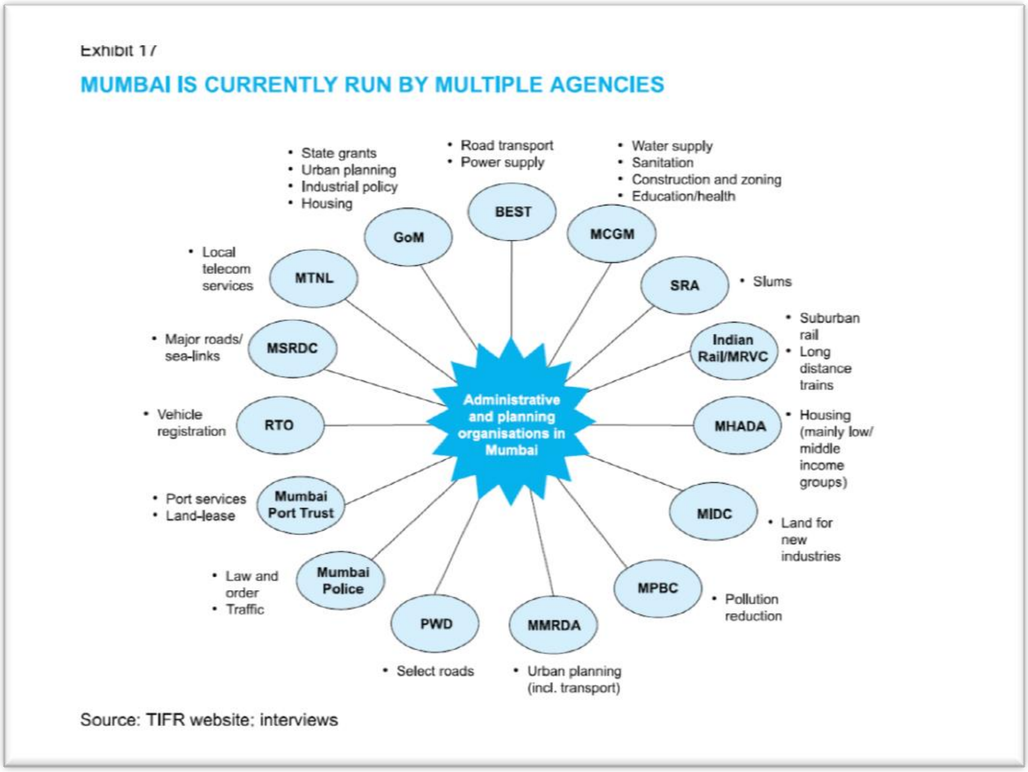

Figure 3.3: Agencies 'running' Mumbai (Source: Vision Mumbai by Bombay First and McKinsey, 2003)

I am interested in the agencies and policies acting in three interlocking areas: the environment (especially climate change issues); housing; and water infrastructure. As can be seen in fig. 3.3 the responsibilities of the different actors overlap considerably especially in regards to housing and planning, whereas water is under the sole jurisdiction of the Municipal Corporation of Greater Mumbai (MCGM). The environment is not mentioned in its own right and with only the Maharashtra Pollution Board Control (MPBC), which deals with pollution, solely targeting environmental issues. As figure 3.3 and table 3.1 demonstrate: several government agencies, and other institutions, are involved in governing responses to environmental issues affecting Mumbai. This separate working of the departments is a concern for environmental issues that cut across so many different departments. Fig 3.2 simplifies the situation and gives no indication of hierarchy or power structures. I discuss the policies in table 3.1 to add context within the sections below. Institutions, NGOs and individuals are also involved in governing Mumbai and will be discussed more fully in Chapter Five.

Agency	Level	Policies	Impact in Mumbai
Government of India (GoI)	National	Coastal Regulation Zones (CRZ) ULCRA (1976)	To protect natural environment but also applies to 'brown field' sites and can limit development. No building can be constructed close to the coast, but in Mumbai the whole city is near the coast.
Municipal Corporation of Greater Mumbai (MCGM[2])	Greater Mumbai	Water supply Mandatory rainwater harvesting Construction Zoning EcoHousing??	Responsible for providing water supply including enforcing legislation for rainwater harvesting to be installed in all new buildings constructed on plots over 1000 m^2. MCGM are also responsible for zoning and regulating construction. EcoHousing may be implemented soon by MCGM.
MMRDA	Metropolitan area	Regional plan	MMRDA are responsible for creating the plans that help shape Mumbai's future.
Slum Redevelopment Agency (SRA)	City	Slums	SRA are responsible for the redevelopment of slums, including working with developers.
Government of Maharashtra (GoM)	State	Planning Housing Rainwater harvesting	GoM are involved in both planning and housing in Mumbai. GoM are also involved in the creation of legislation for mandatory rainwater harvesting.
MHADA	City	Housing (affordable)	MHADA are responsible for affordable housing, which has been separated from other typologies.

Table 3.1 Agencies and legislations

The Government of Maharashtra, Mumbai's province, and the Municipal Corporation of Greater Mumbai have identified rainwater harvesting for special attention. As table 3.1 shows, rainwater harvesting legislation has

[2] Also still called the BMC (BrihanMumbai Municipal Corporation)

been implemented at the metropolitan and at the state level. A policy is in place meaning that all new domestic buildings on plots over 1000m^2 since 2002 and over 300m^2 since 2007 must have rainwater harvesting to obtain permission for inhabitation (Municpal Corporation of Greater Mumbai (MCGM), 2008):

> "…it has been further decided that henceforth, no building permssion [sic] be granted unless provision is made for Rain Water Harvesting Scheme" (Government of Maharashtra, 2007).

This legislation has been put under the administration of the Municipal Corporation of Greater Mumbai (MCGM). The MCGM is of particular interest as the municipality is involved in construction, water provision and rainwater harvesting. The Municipal Corporation of Greater Mumbai has also launched an eco-housing scheme encouraging both the retrofitting of existing buildings and good practice in new construction projects. Developers must register for the scheme and then pay for the rating (quantified results are converted into a star rating) and certification (Municpal Corporation of Greater Mumbai, 2009a, Municpal Corporation of Greater Mumbai, 2009b). Like similar schemes in the UK, these top-down optional assessment schemes have proved hard to implement (see Chapter Five).

3.4 India's middle classes

India's middle classes are growing rapidly, and nowhere is their presence more evident than in Mumbai. Estimates of the number of middle classes in India vary between 50 million and upwards of 400 million people (Fernandes, 2006, Varma, 2007, Mawdsley, 2004). Lemanski and Lama-Rewal (2013) report that the figure has been put at anywhere between six and fifty-four percent of the entire Indian population. This uncertainty arises from the difficulties in forming a general definition of the Indian middle class(es) because of the multi-faceted and ever changing nature of the heterogeneous middle classes (see for example Qayum and Ray, 2011, Fernandes, 2011, Fernandes, 2006, Varma, 2007). The task of defining the middle class is complicated by employment, education, spending patterns, caste, language and also the region of India, leading India's middle class(es) to be one of the most diverse in the world and especially difficult to define (Beteille, 2001, Dickey, 2012). To side step the difficulty of finding an over-arching definition of India's middle class, there have been attempts to categorise them into different sections often using income as the marker (Mazzarella, 2011, Brosius, 2010, Nijman, 2006). Nijman (2006) points out that incomes and costs in Mumbai are higher than elsewhere in India, and so a direct comparison between middle classes across the country is unfair with Mumbai is an extreme outlier. I have deliberately pluralised middle classes throughout this research to reflect the multiplicity of the middle class population. Although there are trends and similarities across India's middle classes, I am particularly interested in Mumbai's middle class population. Mumbai's status as economic capital of India means that the employment and consumption opportunities are different from elsewhere in the country and the city attracts young middle class migrants from across India.

In this section I introduce Mumbai's middle classes and how they are defined for the purposes of this thesis. Firstly I consider how they have changed over the decades from independence to the present day, particularly in terms of employment and consumption patterns. Secondly, I explain how the housing for Mumbai's middle classes reflected these debates on changing consumption. Thirdly, I discuss the growing interest in environmental issues amongst the middle classes in India with reference to community groups and events, and particularly how these interests are manifesting in middle class housing. Finally, I define the middle classes through their housing in the context of this research because housing is a useful signifier of status and a place where environmental interests are enacted.

3.4.1 Changing and growing Indian middle classes

India's elite upper class existed before colonial times within the ancient hierarchical caste system. However many commentators consider the origins of the middle classes to be from the colonialisation of the sub-continent by Europeans, and especially the British who governed India from 1858 until independence in 1947 (Beteille, 2001). The British created a native elite educated in English and with a knowledge of the British bureaucratic systems to facilitate the governing of India's population (Varma, 2007). Nehru's post-independence government was composed of middle class Indians who had prospered under British rule and encouraged a continuation of many policies and so this tool of governance has had a lasting legacy (ibid).

Since independence the Indian middle classes have grown and many have become globalised consumers. These changes have led some scholars to an identify of two types of middle class middle classes, traditional and new (Mazzarella, 2011, Fernandes, 2006, Varma, 2007). Brosius (2010: 14) calls these the "'vulgar' new and 'sophisticated' old" middle classes to reflect attitudes she encountered in interviews. The origins of the traditional middle classes lie in the continuation of the colonial middle classes and they carry forward many of the attitudes and occupations. The new middle class have emerged since independence in 1947 and Varma (2007) argues that this new middle class have grown and developed especially since 1970's.

Although there is no definitive definition of the Indian middle class, there is general agreement that the middle classes relate to types of employment that requires certain levels of education and are usually considered white-collar jobs. Originally this was a small set of careers such as doctors, but has been expanded to include many others in recent decades, such as teachers. The salaries for different white-collar jobs in India vary considerably between those who would consider themselves middle class. This variation is both between types of employment (for example teachers versus bankers) and due to geographical location; a rural salary may not get you far in the metropolis of Mumbai. This is why simple definitions along lines of income do not give the whole picture and the heterogeneous nature of the Indian middle classes is generally accepted (Dickey, 2012, Fernandes, 2011, Mazzarella, 2011).

Patterns of consumption are also key to the understanding of India's urban middle classes, whatever the salary, and the spending of disposable income has changed considerably in recent decades. The traditional middle classes are seen as prudent citizens who want to live well but also save for the future and for the education of their children. The new middle classes, in contrast are seen as spenders who want to demonstrate their wealth as a performance of class, and may even borrow money to achieve the lifestyle that they desire (Fernandes, 2006, Brosius, 2010). "Conspicuous consumption is not only valued as investment in a better lifestyle but as a sign of one caring for oneself" (Brosius, 2010: 23).

Mumbai's huge population is mainly poor working class and under class residents living in informal settlements. But it has been argued that the new middle classes are becoming less sensitive to the plight of the poor (Varma, 2007). The working class rarely have job security and are often employed in the informal (and unregulated) job market. More than half of Mumbai's population live in informal housing, or slums, and this includes most of those who would consider themselves working class and some of the lower middle classes. It should be noted that informal housing and informal employment do not necessarily correlate and that someone in forma employment may reside in informal housing and vice versa. The urban poor live close to the middle classes and the elites because they need each other. So when a new block of apartments is constructed a new eco-system of (potential) employment is created and informal residences are likely to be constructed nearby by those hoping to find jobs (Naipaul, 1990).

3.4.2 Mumbai's middle class homes

Mumbai's role as economic capital of India mean that it attracts young ambitious people from all over India, and indeed the world, particularly for employment in the financial sector (Nijman, 2006). For all the variety within the middle classes, it is stratified and there is a desire to move from one ‘level’ of middle class to the next. This could be simply achieved by moving areas or into a different type of building and the area can be crucial to climbing the social ladder and to personal identity from the reputation of various parts of Mumbai. In this section I describe the variety of middle class housing in Mumbai, but there are three necessary attributes for the middle class apartment. Firstly it must be solidly constructed and in Mumbai middle class housing is almost always legal with occupancy permits in place. Secondly the building and the families within will employ servants to keep their apartments safe, clean and comfortable. Finally the building must be connected to services and the residents will aim for a 24/7 supply (see section 3.6) Uninterrupted services accessed in the home are a marker of status that the middle classes try to attain. The middle classes in Mumbai may use their access to sufficient water supplies as proof of status in line with Kaika and Swyngedouw (2000) who consider infrastructure networks as not merely fulfilling a function but as a status symbol. The ways in which a constant flow of water is achieved in the middle class home is discussed below in section 3.6.2, which describes Mumbai’s water system in relation to middle class apartments. I discuss the first two requisites in this section.

Whilst discussing and evaluating designs for ‘sustainable,’ affordable apartment blocks by masters students at a Mumbai Architecture School, I was surprised to discover that the one-bedroom flats they had designed were each expected to house about five people. These buildings were designed for lower middle class residents and the students had imagined either nuclear families or groups of single people who had moved to the city for employment (Madhiwalla, 2003). Charles Correa remarks that it is the number of people per room that make Mumbai such a densely populated city, not the number of buildings (Correa, 2010). It suggests that the confines of space and the close-knit nature of families embedded within the culture are reflected within the use of space in the home. It also demonstrates the breadth of the middle classes in Mumbai from nuclear families in large apartments to these apartments designed so that a family must share one bedroom or several white-collar workers must live at close quarters.

The type of building an individual lives in can be important, whether it is new and large or an old established society of good standing. Whether you live with a traditional extended family or in a nuclear family or with flatmates can also affect standing within the heterogeneous Indian middle classes. The land and property prices are extremely high in Mumbai and so bungalows, or detached villas, set within their own grounds are the preserve of some elites and traditional upper-middle class. I found that locals knew which bungalows were owned by Bollywood film stars in the suburbs of Mumbai. The middle classes reside in apartments of varying size, position, age and quality. I have determined two main sub-groups, which also relate to the types of rainwater harvesting installed within them: the small established suburban apartment block and the new multi-storey luxury towers in South Mumbai.

The small suburban apartment block is between four and twenty storeys tall and is generally occupied by what would be termed the traditional middle class, but also attracts young white-collar migrant workers taken in as paying guests[3]. These apartment buildings are sometimes extended vertically to increase the number of floors, and other buildings are demolished and rebuilt into much taller buildings, with the original residents making a large profit from the sales. Such a building is represented in the novel *Last Man in Tower* in which a developer wants to demolish the building for redevelopment, a timely illustration of the shift in trend from old established buildings to new buildings that display wealth (Adiga, 2011). The book is a parable of the changing norms of middle class aspirations that have also been observed by Varma (2007), Quayam and Ray (2011), and Mazumdar (2007). These small established suburban apartment buildings are where rainwater harvesting retrofits are taking place to secure water supplies, reduce local flooding and address environmental concerns. The new build apartment buildings described in section 3.5.4 attract residents

[3] Lodgers

who would fit into the 'new' middle class: the young globalised group who value conspicuous consumption and can demonstrate this through their choice of residence (Fernandes, 2006). These buildings usually have extensive grounds (to comply with FSI regulations) and will often have their own gymkhana with swimming pool for the exclusive use of residents. It is surprising that these are the buildings in which the rainwater harvesting systems are often there only to meet the targets for occupancy certificates, rather than with concern for environmental issues because environmental issues are growing in popularity.

3.4.2.1 Household servants as status marker

The middle classes position themselves in relation to the urban poor majority and try to distance themselves whilst emulating the urban elites in a similar way to which their predecessors imitated the British colonialists a century ago. Mumbai's middle classes employ poorer residents as part of their everyday lives. Many roadside store-holders and hawkers4 are kept in business by middle class customers, whilst at the same time middle class neighbourhood organisations petition for the removal of encroachments and hawkers (Baviskar, 2011). The middle classes also create direct employments by having servants and again there is tension in the desire to have the informal settlements in which the servants live far away and unseen, as discussed in Chapter Seven, but wanting their employees nearby and wages low. "… the ready availability of cheap domestic labour in Indian middle class homes impacts everything from the structure of the household economy, the gendered division of labour, and the consumption patterns of even relatively affluent families" (Mazzarella, 2011: 2). The different parts of society need each other in the city and use each other to get ahead: the poor gaining employment as servants from the middle classes and elites, whist they use their servants to demonstrate their position in society and create a middle class lifestyle. The employment of servants has been used for centuries as a signifier of a family's middle class position (Varma, 2007). Employing servants is another way to signify status and so employing extra

[4] Street vendors. Usually unlicensed and carrying their wares in bundles or on a handcart.

servants, such as a driver, cannot just make life more comfortable but also change your status. Employing servants has been used to confirm status for many years, and can be seen as a continuation of colonial practices (Varma, 2007, Qayum and Ray, 2011).

Most middle class homes have servants such as a maid and a cook who might visit the home for one hour each per day, or in some cases (particularly if a member of the household is in poor health) might live within the apartment, as they might have done in bungalows before (Qayum and Ray, 2011). The employment of servants is used as an expression of middle class status (Varma, 2007, Qayum and Ray, 2011). The apartment building's administration will also employ people such as the watchman who guards the building and washes cars and perhaps a bin lady to collect and sort household waste, appointed by the cooperative committee and paid through annual subscription. The employment of servants in the home is central to this research into the culture of living and rainwater harvesting in Mumbai because it may have an effect on the uptake and development of technologies as discussed in Chapter Seven. Bringing a person into the socio-technical system of the home to undertake practices is cheaper than purchasing labour-saving devices and also provides the companionship and status gained through employing others (Qayum and Ray, 2011). The employment of servants is central to the securing of middle class status and lifestyle, in which rainwater harvesting also plays a part by allowing water practices to be less restricted. This employment of domestic servants creates permeable boundaries to middle class homes, as described by Sara Dickey (2000) in the context of Madurai in Southern India. Although the context of Mumbai is very different, there are striking similarities that are explored through empirical work in Chapter Seven, when considering how harvested rainwater is used within middle class housing.

3.4.3 Mumbai's middle classes and the environment

The middle classes are effected by environmental variations and extreme weather events as the discussion of consumption patterns shows they may lack the funds and resilience to re-coup their loses. In contrast, the elites are likely to have the money and contacts to recoup their losses. Poorer citizens in informal settlements or pavement dwellers are most vulnerable to extreme weather events and environmental variations, which can destroy their livelihoods as well as homes and can trap them in a poverty cycle. However they may have the skills to re-auto-construct their homes after a flood or demolition, unlike the middle classes. In this section I discuss the rising coverage of environmental issues in English-language print media and the increase in middle class groups and events inspired by environmental concerns.

Some initiatives are influenced by the bourgeois environmentalist ideology that means an environmental rationale is used to promote issues beneficial to elites and middle classes ideals over and above wider social and environmental benefits (Mawdsley et al., 2009, Baviskar, 2011, Mawdsley, 2004, Das, 2003). Bourgeois environmentalist concepts are sometimes used to justify the clearing of slum areas in the name of protecting the environment and leading to questions of urban environmental justice (Sen, 2010, Mawdsley, 2004, Das, 2003). There is a strong civil society in India, and it can be argued this is the coupled with, and because of, a weak government (Das, 2013). The middle classes are central to this strong civil society and form community groups to promote their concerns (Zérah, 2007). The middle classes have a disproportionate influence on the state due to their civil society organised groups and presence in the media, and in government itself (Mawdsley, 2004, Das, 2013).

One initiative that brings together residents from middle class buildings to form community groups centred loosely on environmental issues is Advanced Locality Management groups (ALMs) Groups of interested residents work with the municipality to raise and address issues to keep local environments clean and healthy, and also to regulate behaviour towards the environment (Anjaria, 2009, Zérah, 2007). This is the middle classes moving to work with the municipality and increase their influence in the local area to promote their own issues and environmental agenda. I attended an ALM area meeting and found it being co-opted by residents complaining about encroachment and demanding slum removal from their areas. There is a tangible tension in this NIMBYist (Not-in-my-back-yard) debate (Patel, 2006) as middle class residents do not want slums in close proximity to their homes but at the same time want to employ and retain servants who live there.

Events such as no-car days in suburbs of Mumbai, bike rides (Indian Cyclists Network, 2012), tree-planting (The Sapling Project, 2012) and rainwater harvesting retrofits demonstrate the growing interest in environmental causes but the approach is not coordinated. On no car days a road is cordoned off and pedestrianised for the day and people are encouraged not to use their cars that day. Events promoting environmental ideas are held on the closed street and there are also stalls promoting 'green' products. I attended one of these events on Carter Road (coastal road in Bandra, a north western suburb) with the secretary of a building I had been touring to look at the rainwater harvesting installed.

The English language print media in India appeals to and promotes middle class interests, and so increases in certain subjects in articles and advertisements can be considered as indicators of changing attitudes (Fernandes, 2000, Fernandes, 2006, Brosius, 2010) I have noted the rise in articles and adverts promoting environmental ideas as a sign of growing interest. Thus, the interest in environmental issues is manifesting across the middle classes however the responses are different between the liberalised 'new', or what I would term 'young', middle classes who desire to buy a ready-formed 'green' apartment, and the established middle classes who want to invest in the buildings that they already have to improve resource security through retrofits.

Rainwater harvesting retrofits have become popular within middle class communities as a key way to respond to environmental variation and ensure a water supply. The retrofits enacted by the established middle classes were found in this research to be embedded in ideas of environmental citizenship and resource security. However, there is a growing fashion for new builds to be 'green' and this highlights the aspirational position of environmental discourses as global issues

Middle class interest in environmental issues has various motivations. Firstly there is evidence in genuine concern for the local environment, and a wish to reduce the impacts on nature. This sometimes stems from religious beliefs, such as the Hindu concepts in *Vastu Shastra*, 'the science of construction'. However these concerns are sometimes a green wash over bourgeois environmentalist aims to clear lower class people from local areas, especially to justify the removal of informal settlements. Secondly, the globalising middle classes are aware of the international debates about climate change and the environment. Those educated abroad may have a great deal of knowledge about these issues, and on returning to India have a desire to enact changes (see interview with US educated developer in Chapter Five). Thirdly, the environment has become a fashionable thing to be interested in, as shown by the rise in special issues of magazines and the advertising of products and properties as being 'green' to sell more to the aspirational middle classes. Finally, some of Mumbai's residents are striving to create and maintain a middle class life style through appropriate technologies that happen to be considered environmentally friendly. Some of these residents take the opportunity to learn more about environmental issues but for others these

3.5 Mumbai's housing

Mumbai is simultaneously home to the most expensive single-family dwelling in the world (The Antilla Building) and the largest slum in Asia (Dharavi). This leads to Mumbai being characterised as a city of extremes and this research aims to address the housing in-between. To address this, I firstly interrogate the crisis of both luxury and informal housing and discuss where middle class housing sits between these. Secondly, I outline planning policies and this leads to the third section in which I discuss the housing market and the legislation shaping it. The shortage of land makes the housing situation and market in Mumbai unique and contested. Finally, I describe middle class housing in Mumbai's suburbs as the site for this research.

3.5.1 Slums to high-rise luxury: the multiple city

Bombay first became urbanised during the colonial era as it became a central port for trade routes to Europe and this has shaped the land and housing situation in contemporary Mumbai. Official boundaries of Bombay have expanded steadily from colonial times under British rule to encompass the island city and Salsette Islands (where the suburbs are), and to reclaim land from the sea, to become Greater Mumbai (Masselos, 2003). Housing for the poor and migrants to the city has also been an issue in Mumbai for centuries. The provision of affordable housing for the poor was used to justify the reclaiming of land from the sea during colonial times under the British, but the land was used for other purposes.

The slums in Mumbai have been estimated to account for up to 60% of the population of the megacity leading to the nickname 'Slumbai' (Pacione, 2006, Pendse, 2003, Municipal Corporation of Greater Mumbai (MCGM), 2007). The informal settlements in Mumbai, as in many cities, are in extremely vulnerable locations on flood plains and other marginal lands (Davis, 2004, Revi, 2008). The 1995 Slum Rehabilitation Scheme is still the policy used today in Mumbai but re-housing schemes have had limited success, and are hampered to an extent by the Rent Control Act, discussed in section 3.5.3 (Mehta, 2005). Thus the housing deficit increases as more migrants enter the city looking for work and populate the slums. Dharavi, the largest and oldest slum area, sits on desirable land in central Mumbai between railways and there have been several plans to redevelop the area, but none have yet come to fruition. However, several smaller slums have been cleared in Mumbai (Sharma, 2007, Graham et al., 2013). At the other end of the scale, the world's most expensive single family home has been constructed in South Mumbai (The Antilla Building is reputed to have cost $1 Billion). There are also luxury bungalows in Malabar Hill near the wealthy financial district. This leads to Mumbai being portrayed as a city of extremes (Patel, 2003).

3.5.2 City planning

Patel (2003) estimates that 6% of the land in Mumbai houses 50% of the residents. The peninsular form of Mumbai that restricts expansion (see fig. 3.2), its colonial heritage and the rapid urbanisation have compounded issues and made planning the city difficult. The Mumbai Metropolitan Region Development Authority (MMRDA) is responsible for drawing up city plans and this is an important process for creating sustainable cities (Bulkeley and Betsill, 2005, Boyd et al., 2009). However there are forty planning authorities in the Mumbai Metropolitan Area and planning additionally involves input from Municipal Corporation Of Greater Mumbai (MCGM), Maharashtra Housing and Area Development Authority (MHADA), Slum Rehabilitation Authority (SRA) and Maharashtra State Road Development Corporation (MSRDC).

Plans for land use are created periodically. One major planning innovation was the creation of a twin city for Mumbai. Navi Mumbai was planned and constructed from 1970 onwards to accommodate commuters to Mumbai and, over time to create jobs within itself, to remove pressure and migration from Mumbai (Sharma, 2007). However, the new city has not been a success in these aims and Mumbai continues to increase in population size.

In the 1980's there was a major change in the housing policies of India towards a market friendly outlook, in which the government was there to aid the process but no longer as housing provider (Sanyal and Mukhija, 2001). This neo-liberalist approach to housing shifted responsibility from the government towards the market and civil society, especially on issues such as slum rehabilitation (Nijman, 2008, Narayanan, 2003). A lack of building regulation leads to the construction of sub-standard dwellings which, when compounded by poor maintenance leads to collapses.

3.5.3 Housing market

Mumbai has one of the most expensive land and property markets in the world (Sharma, 2007). However, Narayanan (2003) and other have argued that it is not the availability of land that is the issue, but rather the affordability of properties. Apartments constructed to be affordable for poorer residents are often instead sold to well off residents. There are three pieces of legislation that are affecting the housing market in particular, and are discussed here: the Rent Control Act; Urban Land (Ceiling and Regulation) Act; and Floor Space Index.

Rent Control Act (since 1948), which protects tenants in Mumbai from eviction can lead owners to neglect properties in the hope that tenants will move out, sometimes until the property collapses or is demolished in a way to regain control of their asset (Banerjee-Guha, 1989). The Rent Control Act is a regulation for existing properties that froze the rent in properties whilst the tenants remain. This has led to buildings not being maintained, as the landlord wants the tenants to move on, whereas the residents want to stay, and pass the property on to the next generation with the low rents in this very expensive city. There have been several attempts to phase out this law, and this process is ongoing.

Urban Land (Ceiling and Regulation) Act (ULCRA) was implemented in 1976 during the Emergency[5] with the aim of redistributing land more evenly and discouraging construction of luxury buildings (Narayanan, 2003, Das, 2003). The law never worked and ULCRA was repealed in 1999, however, the law was only rescinded in Maharashtra in 2002, and immediately replaced (Narayanan, 2003). Narayanan (2003) finds that a lack of control has led to apartments built for poor residents being purchased by the middle classes and believes that the real winners from ULCRA are the large land owners and builders. Corruption and mafia support may also be helping developers circumvent these regulations (Sharma, 2007).

Floor Space Index[6] (FSI) is a key concern of developers as it dictates how large the footprint of the buildings can be and how many floors, thus controlling the amount of profit that can be made. The heights of new apartment buildings in Mumbai are steadily increasing as the developers'

[5] Prime Minister Indira Gandhi and President Fakhruddin Ali Ahmed declared a state or emergency for 21 months allowing 'rule by decree', which made laws easier and faster to pass.

[6] Often referred to as Floor Area Ratio (FAR) in other parts of the world.

focus on floor area ratios becomes an obsession and is exploited by builders to increase revenue. A survey of 20 architects I carried out pointed to the FSI and associated monetary gains as the major factor shaping housing in Mumbai. FSI has some important implications for the environment as it means that open spaces are retained, letting sunlight reach street level and leaving planted areas to cool the air and absorb rainwater. Mandatory rainwater harvesting is discussed later in this chapter. Slum redevelopment schemes have become a central part of the FSI debate because the resettlement of slum residents is used to unlock access to city centre land. Developers then get a higher FSI to develop the remaining land, for a greater profit (Sharma, 2007, Das, 2003).

3.5.4 Middle class housing

Housing for the working class and urban poor under class in Mumbai has garnered attention due to its inadequacies and the high percentage of residents living in slum settlements (see for example: Das, 2003, Mukhija, 2001, Datta, 2012, Roy, 2011). However there is little discussion around middle class housing, which reflects the level of research into the Indian middle classes in general. The middle classes of Mumbai now generally live in *pukka*[7] apartments within buildings usually run as private co-operatives, as explained in Section 3.5.5. The apartment building is the relatively new home of Mumbai's middle classes as they have moved from bungalows and smaller buildings (Qayum and Ray, 2011). Mumbai's elite and middle class developments are usually legal and illegal housing is portrayed in most academic and political debates as being informal slums (Datta, 2012). However in other Indian cities, and particularly in Delhi, the situation is more complex and well-constructed apartment buildings and even shopping malls may turn out to be illegal and lack the necessary permissions (Ghertner, 2011, Roy, 2011, Lemanski and Lama-Rewal, 2013).

As the middle classes rapidly expand in India, new apartment blocks replace bungalows and small blocks of flats as urban areas are (re)developed due to spatial constraints and the high costs of real estate and this is eroding the

[7] A *pukka* house is of sound construction, and usually legal in Mumbai

co-operative set-up. The area of Mumbai that this research centres on is Greater Mumbai, in particular the north and western suburbs where there has been a great deal of construction of high-rise apartment blocks as well as the digging-in of middle class heels to stay in their low-rise apartment blocks.

Figure 3.4 Middle class housing: Kanti Apartments (Source: Author)

A new architectural vernacular of concrete tower blocks can be seen emerging in Mumbai following liberalisation of the housing market in the 1990s (Nijman, 2006). The burgeoning middle classes in Mumbai are further straining the infrastructure with increased consumption and high-rise accommodation (Correa, 2010), which brings them into focus as an important part of the climate change mitigation discussion. The construction of new housing to accommodate an influx of population for high-income jobs in financial services and multi-national companies should be viewed alongside the in-migration of the rural poor and migrant workers into the city's informal settlements as both add to the need for improved infrastructure. However the higher income new citizens can purchase their resource security more easily and create the sought-after lifestyle of the new middle classes. It should be noted here that it is not just the number of buildings in Mumbai that gives it a high density of population, but rather the number of people living in each room (Mehta, 2005, Madhiwalla, 2003). The urban poor crowd into slums and onto the pavements and the lower-middle classes share apartments (as discussed in Section 3.4.2). However the upper middle classes and elites demand new bigger air-conditioned apartments with many amenities (Sharma, 2007, Qayum and Ray, 2011). The two are inextricably linked, as the poor are employed to build the houses for the rich and then work there as servants, reproducing social inequalities (Fernandes, 2011). The two also compete for space to build and it is often land previously occupied by informal settlements that is redeveloped into middle class apartment blocks (Das, 2003)

3.5.5 Co-operative Housing

Middle class apartment buildings in Mumbai are traditionally (since the early 20th century, but increasing greatly since independence in 1947) run as tenure co-operative societies within which a share of the cooperative is owned rather than the flat itself (Ganapati, 2008). The National Co-operative Housing Federation (NCHF) was set up in 1969 in an attempt to co-ordinate co-operatives at the national level (NCHF, 2009). A co-operative society elects a president and a secretary to manage the maintenance and upkeep of the building, including the building's relationship with the city's infrastructure, sometimes leading to the retrofitting of rainwater harvesting systems and the digging of borewells. There are examples of co-operatives over-stepping their responsibilities such as limiting who can live in a building even if the owner has agreed the rental (Sharell, 2011). This kind of control can make finding a flat particularly difficult for single people, religious minorities and foreigners, as I experienced myself.

3.5.6 Defining Mumbai's middle classes through their housing

The difficulties in defining the heterogeneous Indian middle classes were noted in Section 3.4 and finding a comprehensive definition of the Indian middle classes is a difficult, and perhaps impossible, task (Mazzarella, 2011, Brosius, 2010, Fernandes, 2011). However, whilst acknowledging the complexities of the debates, I have to determine my research subjects. Thus in this research I have created a definition of Mumbai's middle classes through their housing and the commonalities between middle class apartments are further discussed in section 7.3.4. By using housing as the framing concept I have created a broad definition from empirical observations to aid understanding of emerging patterns.

Mumbai's middle classes are distinct from those in the rest of India because the city's status of economic capital attracts higher wages and a cosmopolitan community (Nijman, 2006). Even though I have focused on one urban area the middle classes are still heterogeneous and constantly changing, making any definition imperfect (Brosius, 2010). I have used housing as the framing tool because it is a clear indication of the developing class structures in Mumbai and the changes in housing and middle classes reflect each other (Nijman, 2006).Therefore I define Mumbai's middle classes for the purposes of this research as living in apartment buildings where the co-operative society, or management, and the residents employ servants.

3.6 Mumbai's water infrastructure

Water supply in Mumbai is inadequate and uneven leading to shortages and inequalities. There are serious justice and equity issues because at current supply levels, the majority of dwellings in Mumbai do not have a mains connection. Much of the literature on Mumbai's water systems rightly focuses on the urban poor's struggle for access. The huge main pipes can be seen ploughing their way through the city and in the informal settlements that line the route they are used as walkways by those who have no access to the water that flows in them (Graham and Marvin, 2001). Even those residences that do have a mains connection have water for only a few hours a day, nevertheless within the middle class apartment buildings, that are the focus of this thesis, an illusion of constant mains water supply is performed for the resident. This not achieved by the 'black-boxing' of infrastructure as discussed in the Global North (see Graham, 2006), but by what is a carefully managed portfolio of (often partially visible) supply routes that needs daily attention at the building level to maintain the illusion. The water for everyday practices is supplied from different sources and through a range of apparatus both in the home and in the city-wide water supply networks, such as water filters to give potable water, *geyser* for hot water, water tankers for extra supply delivery and, as discussed in the following section, tanks that are filled daily to cope with intermittent central supply. Thus water in the home is rarely considered to just happen but is an everyday issue even for the middle classes in Mumbai. The creation of a constant water supply is a socially enacted performance of water that requires effort, maintenance, management and building-level infrastructure made easier by careful planning, new technologies and attentive watchmen[8].

This section first describes the mains water supply in Mumbai looking at its origins in colonial Bombay and the current supply network and governance. This leads to a consideration of the shortfall of this mains supply as the city's population grows. The second part of this section unpacks how Mumbai's middle class use a portfolio of water provision to create the illusion of a plentiful and constant supply, and how rainwater harvesting can fit into this pattern. This begins with a plotting of the different supplies to a middle class home, before looking more closely at each of these routes and how they are managed at the building scale.

3.6.1 Mumbai's direct mains water supply

The provision of mains water in Mumbai has roots in the colonial planning of the city when the existing wells and tanks were insufficient due to drought and urbanisation (Gandy, 2008; Zérah, 2008; Graham and Marvin, 2001). In response, The Water Department was created in 1860 to supply water from lakes through a centralised infrastructure system that is provided and controlled by the government (Gandy, 2008; Zérah, 2008; Graham and Marvin, 2001; Anand 2011) The colonial government did not

[8] A watchman is an employee of the building's co-operative society. He guards the building, including checking visitors to the building, and opens the gates for vehicles. He may also water plants, take deliveries, wash the cars and do other small tasks for residents. They often work in shifts and sleep underneath the apartment building.

have aspirations that mains water would be universally provided and the first system that brought water from Vehar, finished in 1860, only supplied water to wealthy households (Anand, 2011, Gandy, 2008). The water system was popular with wealthy residents and an increase in the number of connections, combined with droughts led to the extension of the Vehar system and creation of the Tulsi scheme by 1879 (both of which still serve South Mumbai), followed by the ambitions Tansa scheme completed in 1948 (Gandy, 2008). Even with these expansions there were still insufficient and uneven water supplies into the city at the time of India's independence. Post independence there have been several more schemes bringing water from distant lakes. The most recent of which is the Bhatsai scheme completed in several phases from 1983 until the present day and several more schemes to increase water supplies are in preparation (Bambale, 2012). Thus the legacy of this centralised system is a reliance on a mains water supply network that falls short of the technical ideal, does not supply all residents and is updated, and new water sources tapped, only when water shortages are felt by wealthy residents.

Although the network of supply pipes has been extended, it has not kept up with urban growth and a shortage of water supply has been created. Mains drinking water now comes from several reservoirs or lakes outside the city but is only supplied for a few hours per day to each area of the city (BrihanMumbai Municipal Corporation, 2003, Sule, no date). Water is only supplies to buildings that the municipality consider legal and water is not supplied to informal settlements constructed after 1995 (Bambale, 2012). By 2003 the municipality had acknowledged the water shortage and that the problem had accelerated faster than expected:

> "The present water demand of Mumbai is 3400 MLD[9] against supply of 2900 MLD. This difference was expected to grow much higher in 2021 when the projected demand would be 5400 MLD for a projected population of 15.60 millions. But the population is

[9] Million Litres Daily

> almost there today itself & the city is facing water shortage in some areas.” (BrihanMumbai Municipal Corporation, 2003: 1)

The MCGM states that current water supply levels to Mumbai are 180 litres per person per day, which is higher than supplies in London (Bambale, 2012). However due to not all residencies being supplied, the poorly maintained and inefficient network, leakages and thefts, the per capita water supply is much lower than that and the dream of a 24/7 supply for all residents is a long way off (Graham et al., 2013, McKenzie and Ray, 2009). The difficulties in accessing water for the urban poor majority area a daily struggle.

The Municipal Corporation of Greater Mumbai (MCGM, also known as BMC) still bears the sole responsibility for the lucrative water supply in the city, unlike the privatised electricity supplies (BrihanMumbai Municipal Corporation, 2003, Zérah, 2008). Ruet et al (2002) explain that the water supply is still public because of the economic benefits as the returns far outweigh the expenditure, making water a good source of revenue for the MCGM. Although this in some ways limits the commodification of water resources, the lack of an autonomous water agency reduces the efficient management of the system (Bakker, 2010). However Ruet et al (2002) point out that the number of divisions within the MCGM with responsibilities for part of the water infrastructure, and the large number of other institutions involved at the state level in provision of water, has created a very complicated system that has led to failures. And corruption is also a serious problem across all parts of the water supply system (Asthana, 2008).

The municipality draw attention to the water that is pilfered by the residents of informal settlements who have no legitimate access to the mains supply, and the media promote this narrative by often showing the pumps removed in the newspapers (Graham et al., 2013). However the losses from leaks of the ailing system and illegal selling of water for tankers play a more substantial role in the reduction in water supply. The depiction of the poor as the ones at fault for their desperate actions to get water is highly problematic and feeds the well-rehearsed narratives of the middle classes and elites to promote their interests and clear informal settlements (see Baviskar, 2002, Fernandes, 2006, Mawdsley, 2004). This concentration on blaming the poor for theft and encouraging the middle classes to save water through education campaigns diverts attention from other routes such as investing in the current mains supply to remove leakages or selling of the (lucrative) water utility for privatisation.

The water is treated at one of four water treatment plants before being supplied to residences (Ruet et al., 2002). The largest water treatment works is Bandup, which treats water for most of the city and is reputedly the largest and oldest water treatment plant in Asia. The MCGM are proud of the quality of their water supplies although it should be noted that in middle class homes mains water will be passed through a UV filter in the kitchen before it is considered potable and in some households mineral water is bought for drinking and cooking. However the MCGM says that its water supply is potable and the majority of the population (who have little choice) do not filter it (Bambale, 2012, Ruet et al., 2002). A major issue of water quality is the way in which the water is delivered to the residents and how it is stored, with the materials and cleanliness of tankers and tanks (discussed below) necessitating the (re)treatment of water in many homes.

Infrastructure is often hidden from view in the Global North and this opacity means that individual moments of failure, such as blackouts, suddenly make the consumer consciously aware of the service and may reveal the inner workings of the systems (Graham and Thrift, 2007, Gandy, 2004, Kaika and Swyngedouw, 2000). Mumbai's water infrastructure is not highly 'black boxed' in this way: pipes are visible and supply is differentiated such that water provision processes are not obscured. These visible pipes and wires alter the ways infrastructures are experienced and encountered both within domestic buildings and on the streets of Mumbai. The exposure of the infrastructure network (see fig. 3.5) may be accidental, or at least appear to be, but it also has several practical implications. Firstly it allows for ease of maintenance, making it easier to repair, replace or adapt. This allows for access when things go wrong and also for daily resource management. For example, the tank must be filled and the 'geyser' [electric water heater] switched on to heat water. Secondly, when new infrastructures are installed they are often placed on top of existing surfaces or other infrastructures for ease of installation. The transparency of infrastructure and the maintenance processes can lead to innovation but leaves the systems vulnerable to what the municipality consider theft, a condition necessary to those without access and caused by social and political pressures.

Figure 3.5: Visible infrastructure (Source: Author)

The municipality are just one of the actors in a system of supply and governance (Bulkeley and Betsill, 2003; Graham et al., 2013; Zérah, 2008). Beyond the centralised supply, several other institutions and individuals are involved in the water supply portfolio, further complicating the systems of water supply and sewerage (Nallathiga, 2006). This is evident in the provision of tankers by private enterprises and the 'water mafia' to fill demand. The MCGM acknowledges that there is a shortfall in this supply and this has led the municipality to implement water-saving tactics and to shift responsibility on to the consumer in ways already enacted in middle class residences.

3.6.2 Water supplies to middle class apartments in Mumbai

"The landlord had a tap turned to stop the water of a dripping pipe in my flat but unfortunately this also stopped the supply to the water filter that gave us drinking water. My landlord explained that there are three separate supplies to my flat in Mumbai, but he's not sure which supplies what. The first is the direct mains connection, the second comes from roof/attic tanks (filled by BMC water) and the third source is a bore-well (this water is mainly used for flushing toilets). This differentiated system works well to help the residents cope with the unreliability of the water supply."

Box 3.1 Excerpt from author's research diary (Mumbai 08/01/2010)

Drawing on my own experiences of living in Mumbai I learnt about the differentiated nature of the water supply to middle class homes and how it can impact on lives when it is misunderstood. The above excerpt from my research diary demonstrates the complexity of the water supply routes at the building level and how residents may not be aware of them. It also suggests that it could be possible to live off the water grid in Mumbai, if appropriate sources were used to supply the multiple water supply routes into the apartment, and in times of shortage this may become necessary. In Mumbai disconnection from the water supply occurs on a daily basis and in middle class residences these small infrastructure shocks are reacted to in a variety of ways that build resilience, including rainwater harvesting. "Disconnection produces learning, adaptation and improvisation. All infrastructural systems are prone to error and neglect and breakage and failure, whether as a result of erosion or decay or vandalism or even sabotage" (Graham and Thrift, 2007:5). Working and hidden infrastructure causes separation from particular ideas about nature and thus has been shown to cause increased consumption by reducing awareness of the provision mechanisms and increasing convenience (Kaika, 2005, Shove, 2003a). Most buildings will have other sources of non-potable water for flushing toilets or just for outdoor use (as explored in Chapter 7). Thus the position of Mumbai's water infrastructure as a visible part of life could help reduce consumption and at the same time it could be argued that supplementing the supply with rainwater to give the illusion of plentiful resources might increase consumption and negate any environmental benefits.

The water supplies to a middle class home are differentiated on entering the building compound. The main point of differentiation is between potable and non-potable water, which correlate with specific taps and other outlets in the building, as shown in the schematic diagram (fig. 3.6). The alternative sources include bore wells (used to access groundwater and aquifers) and underground storage tanks filled with water delivered by water-tankers, which can be ordered in times of water shortage. In this section I use the water supplies to the home as a starting point to unpack the water supply system across Mumbai as a whole, by investigating the four water sources in turn and then considering how rainwater harvesting can fit into this portfolio of water provision. This tracing of the water supply begins a continuation of the discussion above of the largest water supply into Mumbai's middle class homes, the municipal-supplied mains system. I then briefly discuss the use of bottled water to supply further potable water. Thirdly, the use of water trucks is explained from both the point of view of the middle-class domestic building and the supply to informal settlements, to consider some of the justice issues around water supply in Mumbai. Ground water drawn from wells is then considered as the fourth major source of water. Finally rainwater harvesting is discussed in relation to the other sources.

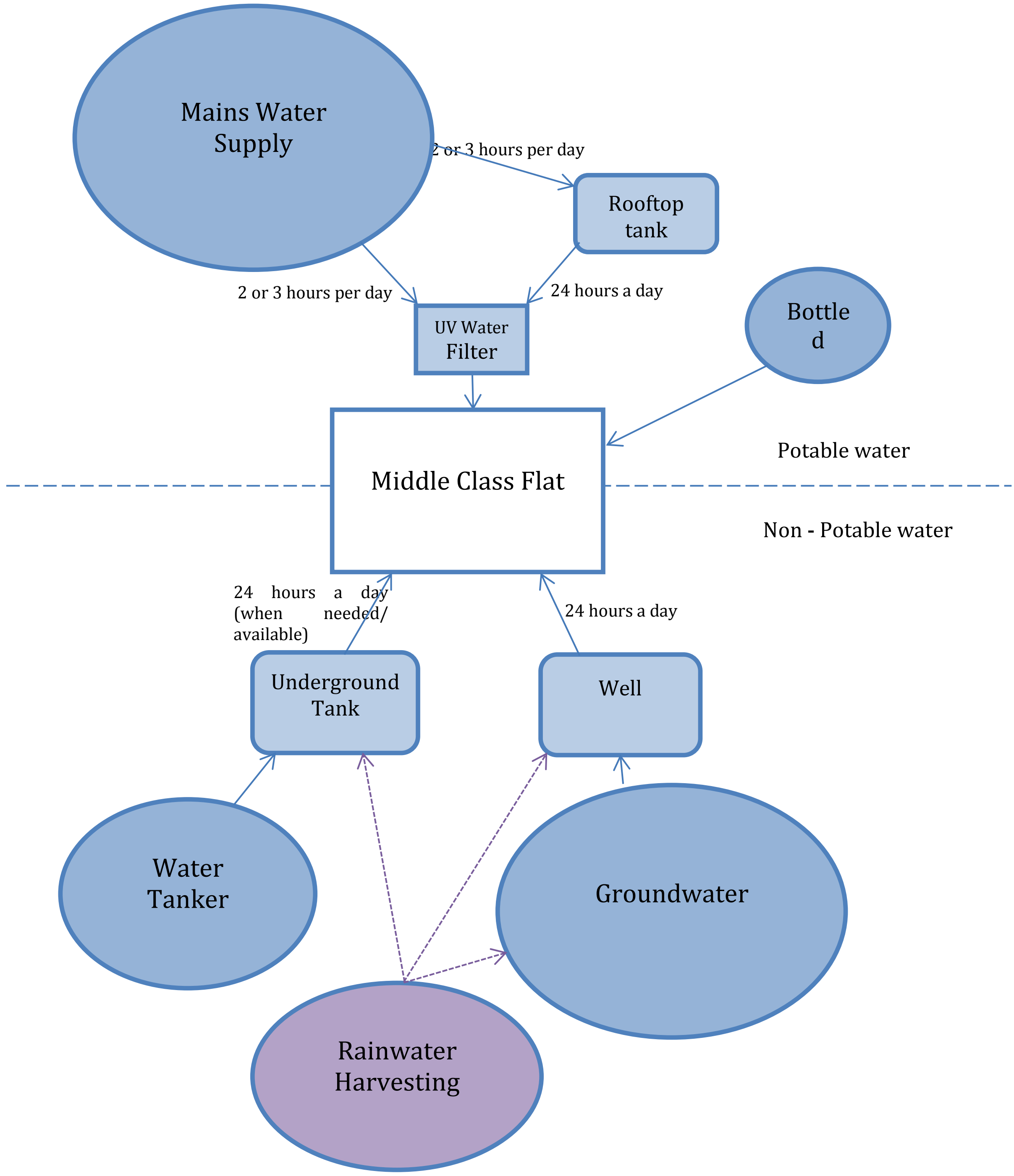

Figure 3.6: Schematic diagram of water supplies to middle class housing (Source: Author)

3.6.2.1 Mains supplies and roof top tanks

Mains water remains the major source of water for Mumbai's middle classes but, even to middle class domestic buildings, the centralised mains supply is not constant and is supplied for approximately 2-3 hours per day. The hours that the supply flows depends on the area in which the building is situated and the supply rolls out across the city from the treatment plant at Bandup (or one of the three smaller plants) (Gandy et al., 2007). To cope with this intermittent supply, tanks are installed in the roof spaces of apartments or on the roof terrace of buildings and filled daily when the water is flowing for use throughout the day.

In middle class housing an illusion of constant mains supply is created through the storage of mains water in these tanks to be used at other times in the day, and supplementation by other forms of decentralised water supply for non-potable purposes, such as tankers and borewells, as seen in fig. 3.6. For poorer households, mains water connections are often from stand-pipes in the street, shared between several households and water must be collected in buckets whenever the taps spring to life (Anand, 2011, Graham et al., 2013). Many other informal residents have no mains connection at all, leading to a reliance on expensive water tankers run for profit by middle men (such as the one in fig. 2.1) or the creation of illegal connections to mains water pipes (Graham et al., 2013). These connections may not always be appear illegal to the residents, who may have even paid money to government officials, only to later discover that corruption was involved and their water supplies are illegal and they are removed.

In the colourful autobiographical novel *Shantaram*, the water for the protagonist's shower is delivered in pots and carried up the stairs by working class men to fill the tank (Roberts, 2004). In the book he is embarrassed when he realises that these men are having such exertions for him to shower but is encouraged to take even more showers to create local employment. The watchman in an apartment building usually carries out the process of managing the water storage, with instructions from the co-operative society members, to ensure a constant supply to point of use in the building. This is achieved by monitoring when the municipal supply is flowing and turning taps to ensure that the roof tank is filled and that it can then be accessed a few hours later when the municipal supply has stopped again. The municipal water is used for indoor practices, such as bathing and this is also the drinking water in most middle class homes, although to make mains water potable (in the opinion of the middle classes, see Chapter 7) it is run through an ultraviolet filter before use for drinking or cooking.

3.6.2.2 Bottled water

Bottled water is another supply of potable water for the middle classes and elites. Some elite and middle class citizens of Mumbai do not drink the water from the taps, even after filtering, believing that this packaged water is of higher quality. Therefore in some apartments the drinking water is differentiated even further and separated from the city's system of pipes entirely with mineral water delivered in refillable 20 litre bottles each with a tap at the bottom for ease of use (see fig. 3.7) delivered from a local supplier by working class men on a hand cart. This method of getting water is further discussed in Chapter 7, when water usage in the home is considered.

Figure 3.7: Differentiated water supply. Bottled drinking water (Source: Author)

The Bisleri water-bottling plant at Andheri in Northern Mumbai is a controversial moment in the metabolism of water through the city as it draws in ground water to process, add minerals and package (Bisleri, 2013). The main benefit of this system to a resident is that the capital costs and maintenance requirements for achieving what is considered a high quality supply of drinking water are less than for running a UV filter, such as those attached to the mains water supply. This removes the need for high capital investment in a water filter that then needs maintenance as well as creating a whole new water source that is removed from municipal control, but is an expensive way of accessing drinking water. Thus the rich are creating an alternative water metabolism pathway that excludes most Mumbaikars, including those that deliver the water containers on hand carts.

3.6.2.3 People as part of Mumbai's water infrastructure

The middle classes rely on the hard work of working class men to deliver and supervise the supplies of water into their homes and maintain constant supplies. Thus the fragmented infrastructure is supplemented by people performing roles of infrastructure and constant water supplies to middle class homes are assured through this utilisation of people in place of embedded, centralised infrastructure networks. Simone (2004) explores the use of people as infrastructure in Johannesburg and shows that people can constantly work to change the shape of infrastructure and keep that city going. "This infrastructure is capable of facilitating the intersection of socialities so that expanded spaces of economic and cultural operation become available to residents of limited means" (Simone, 2004: 407). Many parallels can be drawn between the infrastructure provision in Johannesburg and Mumbai. The variety and flexibility of water pathways is crucial in Mumbai, where supply routes are unreliable. People used to bring, carry and supply resources and keep the process of infrastructure flowing, Mumbai is able to keep functioning. This does, however, rely on the continued availability of cheap labour.

A recent Bollywood film *Dhobi Ghats: Mumbai Diaries* deals with the materiality of Mumbai and the very different experiences of life in the city[10]. The film is notable in the infrastructure discussion because one of the

[10] There is an interesting shift in the film industry towards the Indian city as a major character in films and not merely a backdrop and Bollywood films such as this one can be seen as archiving the city: especially the industry's home, Mumbai. See **Mazumdar, R** 2007 *Bombay Cinema, an Archive of the City* University of Minnesota Press, Minneapolis..

characters is a dhobi and links together several of the characters by delivering this service. Another character, who is researching livelihoods, follows him for the day and so we get an insight in the flows of laundry and water from the house and back again as she performs an ethnography of this infrastructure (Star, 1999). This questions the boundaries of the home when the material flows are such an integral part of domestic life. The presence of the dhobi in this particular film demonstrates the normalcy of this service (and of researchers) to residents and reveals to them some of the details of the process. As will be discussed in Chapter Seven, having people as servants in the home also affects the relationship to infrastructure and technologies. Convenience of the middle classes and elites is created, not by the use of labour-saving devices, but by hiring labour from people who do not have access to water in their own homes and this highlights justice issues around access to resources.

The inclusion of people as part of water infrastructure is highly gendered in Mumbai. The paid work to maintain water supplies to middle class residences is undertaken by men, but the unpaid collection of water for less wealthy families, with no water connection, is usually undertaken by the women of the household. In an area with communal standpipes, for example, the women must be ready and available to collect water in containers whenever it starts to flow in their neighbourhood (Datta, 2012). This can mean starting the day very early and can also impact on girls' education if they are required to stay at home to help with these chores (Gandy et al., 2007, Bapat and Agarwal, 2003). It is a time consuming, disruptive and sometimes dangerous task with long queues, unpredictable timings, and busy roads to cross and frequent altercations over the distribution of water. When the water supplies are insufficient or unavailable, the residents turn to water vendors reselling expensive water from their own connections, wells or water tankers (McKenzie and Ray, 2009).

3.6.2.4 Water tankers and underground tanks

Water tankers are a main source of water supply to many informal settlements, especially those not recognised by the municipality as being constructed before 1995 Water tankers are used to deliver water to properties and individuals without a water connection but also used by the middle classes to top-up their supply by filling underground tanks. The tankers are often filled with water from the mains supply by the water vendors, either legally, illegally or as a result of bribing officials (McKenzie and Ray, 2009, Gandy et al., 2007). The water is thus technically potable water, although by the time it has been in the tanker and then sat in an underground tank the quality has been impaired, by particulate matter and micro-organisms, and middle class residents will not drink it.

Corruption and racketeering is endemic in the provision of water tankers, leading to this loosely connected group of people involved in water vending as being described as the 'water mafia' (Graham et al., 2013, Gandy et al., 2007). It is not unknown for tankers full of drinking water to be diverted to building sites or to Bollywood sets (Graham et al., 2013) . In times of political wrangling, such as elections, water tankers are often publically delivered to informal settlements in a move to secure votes from the residents.

Mumbai's infrastructure of water provision for the middle classes can be described as: visible, differentiated, and therefore adaptable. The water tanker sums up these three interlocking properties of supply by being highly visible, used only for certain practices and capable of being called to any area at times of shortage to substitute for another water source. This is possible partly through the differentiation of the supply to middle class housing, meaning that the tanker can be used to fill the tank and that water will only be used for certain practices, critically it will not be sent to kitchen taps and so not used not used as potable water. The underground tank is filled and used when necessary – the accessibility and differentiated nature of the water supply to housing allows for different sources to be supplied for different practices around the building. These tankers are an expensive way to secure a water supply and some middle class residents are now turning to rainwater harvesting as a cheaper option to fill their underground tanks that also gives them more control.

3.6.2.5 Wells

Wells have been used for supplying water in India for hundreds of years. The use of dug up wells (groundwater) and bore wells (aquifer) in urban areas has been growing in recent years. The ground water table is dropping, and aquifers are being emptied, so new wells must be dug deeper and old wells are drying up (as discussed further in Chapter 6). This also leads to the encroachment of saline water into the ground water supply, which becomes unusable (Bapat and Agarwal, 2003). Rainwater harvesting is one way or replenishing the ground water and could help to push back the seawater encroachment. There are now strict regulations on the digging of new wells in an attempt to regulate the amount of water drawn from the ground.

Middle class domestic buildings have water pipes snaking up their façades with red painted pipes denoting borewell water, sometimes from rainwater harvesting. They must be painted red as borewell water is prohibited from being used for bathing, cooking or drinking due to high bacteria and particulate content as well as discolouration and often an unpleasant smell (as explored in Chapter 7). The many visible pipes on the façade demonstrate the differentiated nature of the water supply, allowing rainwater harvesting to be more easily incorporated into the assemblage of supply and added as a novel pathway. The visual nature of the infrastructure leads to higher awareness of provision.

3.6.3 Rainwater harvesting

Rainwater can be substituted into the domestic water supplies into a tank or to replenish water supplies to a well, as seen in fig3.6. In simple terms rainwater harvesting is the collection of precipitation but there are many different ways to configure a rainwater harvesting system depending on the specific circumstances and thus the process itself. Rainwater harvesting was observed during fieldwork mainly as retrofits, primarily instigated by residents. Rainwater harvesting can be used as an adaptation to water shortages by collecting and using the rainwater which in turn reduces consumption of treated mains water often drawn from outlying areas. It also reduces localised flooding by collecting the water thus helping the citizens to adapt to extremes of weather. In new build projects the rainwater harvesting systems were generally used to percolate the water into the ground, which replenishes the groundwater and can reduce localised flooding in the grounds of the building, as suggested by Prabhu (Municipal Corporation of Greater Mumbai (MCGM), 2013), but does not directly augment the water supply of the building. In this section I will introduce the historical usage of rainwater harvesting and consider its transition to contemporary urban use.

3.6.3.1 Rural origins and transition to contemporary urban areas

Rainwater harvesting is an ancient technology that has been used in rural areas of India, and other countries, to collect and store rainwater. Villages in Northern India, where water is scarce due to low rainfall, have collected rainwater for use by the community for centuries, particularly for watering crops (Pandey et al., 2003). In Rajasthan traditional step wells are still found in some villages, but many are no longer used. When main supplies reach villages or borewells are dug, many stop the traditional use of rainwater harvesting. Large important buildings such as temples and palaces had systems in place to ensure a water supply. These are sometimes highly decorative, such as the example shown in fig. 3.8. In that system at the Fatipur Sikri complex in Northern India the harvested rainwater is kept in a tank underground. The harvesting of rainwater in this instance also had tactical advantage that the complex had a fresh water supply in times of siege. When I visited some people were withdrawing water from the tank, demonstrating that it is still working and in use.

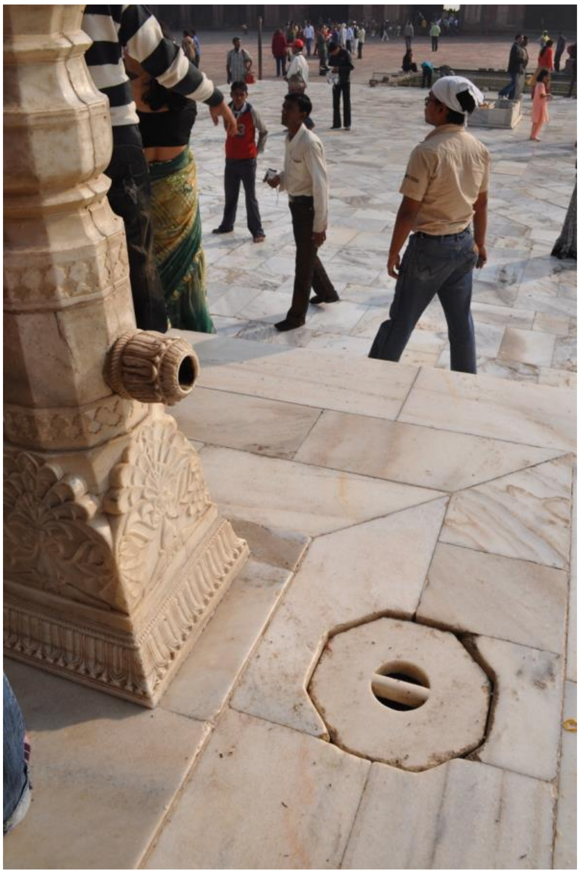

Figure 3.8 Ornate rainwater harvesting spout at Fatipur Sikri (Source: Author)

Decentralised supplies of water and electricity are considered only as secondary systems by urban residents to supplement centralised mains supplies. As Karen Bakker (2010: 4) says "The network is assumed to be the norm, and the continued existence within urban areas of nonnetworked technologies of water supply provision controlled by communities is often portrayed as problematic." However at the same time these decentralised systems are being promoted to build resilience and address environmental issues. Pandey *et al* (2003) point to the historic use of rainwater harvesting as an important strategy that could be re-invented for adaptation to climate change in contemporary India. These vernacular techniques to respond to supply water resources are also becoming important for the contemporary urban response to environmental issues. The occurrences of droughts and of water shortage in recent years have increased uptake of rainwater harvesting in Mumbai and given the municipality leverage to implement water policies as the desire for a resilient water supply has increased. Rainwater harvesting technology exists already as a means to provide a more resilient water supply but, despite initiative from the Government of India, there is a lack of political will, funding and capability (Dhar Chakrabarti, 2001, Pandey et al., 2003).

Rainwater harvesting is at a nexus of mitigation and adaptation of environmental issues. It reduces consumption of mains water and thus saves energy used to purify and transport that water. Water is collected and stored or percolated into the ground, rather than running out to sea, which can help to raise the depleted water table. The collected rainwater is often used for specific practices in middle class buildings, such as watering plants or flushing toilets (as discussed further in Chapter 7), made possible by the differentiated water supplies. This substitution of water supplies can save water and alleviate stress on Mumbai's infrastructure, and may mean that the limited supplies from other sources are freed up to be used more abundantly for other practices. Rainwater harvesting also reduces localised flooding that can occur during monsoons and extreme weather events.

3.6.3.2 Rainwater harvesting configurations

There are several main configurations, the key points being: where the water is collected from (grounds and/or roof) and what is then done with the collected water. In Mumbai rainwater is often collected from both the roof of an apartment building and its enclosed concreted grounds using slight inclines and drains. It is the variation in what happens to the rainwater after collection that is concentrated on in this section. The MCGM (2008) has provided suggestions and guidelines for the installation of rainwater harvesting systems into domestic buildings in Mumbai, suggesting 4 configuration that I will briefly discuss:

1. Storage in underground or above ground artificial tanks.
2. Direct recharging of the subsoil water strata (aquifer) through dug up wells or bore wells.
3. Recharging of the subsoil water by percolation.

4. Forcing rainwater in the ground through bore wells and thereby preventing entry of salty seawater in the subsoil strata. (Municpal Corporation of Greater Mumbai (MCGM), 2008: 1)

1. In many regions of the world, such as some rural areas in Africa and in the UK, water is collected from roofs of buildings and stored in tanks either above or below ground (Kahinda et al., 2007, Handia et al., 2003). This is one of the simplest configurations of rainwater harvesting but is rarely used in Mumbai in isolation because the monsoonal nature of the rainfall patterns means that the artificial tank would have to be very large, and this is impractical in such a dense urban area. Thus systems that recharge the ground water or aquifers are favoured, although a tank may also be filled for immediate usage.

2. Water is fed down into a bore well through pebble and sand filters to remove particulate matter. This directly replenishes the original source of the water for the well. This system is popular in retrofitted systems, especially where an existing bore well has dried up or become unreliable, and some residents are reopening old wells to make use of them in these schemes.

3. The water slowly recharges the ground water through unlined trenches (see fig 6.1), percolation pits, porous paving or soakaways, if there is enough space. The water can be later extracted using a well, but in many new build properties the water is simply allowed to recharge the ground water. This system is popular with developers constructing new domestic buildings, as it satisfies the legislation with minimal effort. However it is also popular with retrofitted system, with the addition of a well to withdraw the water for use in the property.

4. The rainwater is fed into a bore well (as in 2), but this is done under pressure using a pump so that the rainwater replaces any saline water that has encroached into the aquifer. This could be a useful system in areas near the sea and can be used to revitalise old wells, however I did not encounter any rainwater harvesting being used to flush saline water in this way.

The type of rainwater harvesting system installed in a property depends on the size of the plot and building, what the water will be used for and the geology of the site. However in Mumbai different kinds of percolation and well recharge are favoured over tanks to reduce the chances of mosquitoes breading and to save space.

3.6.3.3 Rainwater harvesting legislation

"Green buildings also need rainwater harvesting and water recycling. Green buildings reduce costs, not just for residents but also for city level," said Prof. Saugata Roy, Minister of State for Urban Development said at the National Conference on Green Design: Buildings and Habitats (New Delhi, 08/01/2011). Rainwater harvesting is one of the central technologies for 'green' building initiatives (see Chapter 5). The addition of rainwater harvesting in one building does not just help those residents but improves water provision across the city by reducing demand and is suggested as a solution to shortage by the municipality (Municpal Corporation of Greater Mumbai (MCGM), 2008).

> "The civic body also needs the support of the citizens in rain water harvesting. This will not only reduce the burden on the drainage system thereby mitigating flood risk but will also help in augmenting water supply during the summer, particularly during years of scanty rainfall." Sunil Prabhu, Mayor of Mumbai (foreward in Municipal Corporation of Greater Mumbai (MCGM), 2013 : vii)

This again highlights the importance of these alternative water sources for relieving stress on the mains water supply. This has the potential to free water resources for other sections of society, but it is unclear whether this will happen (as explored in Chapter 7). And so technologies, such as rainwater harvesting, are being positioned as solutions to water shortage, which may allow the municipality to roll back provision of mains water. Rainwater harvesting and ground water recharge may also improve water quality from borewells and reduce cracking and collapse of buildings (Sule, no date). The increasing provision of these alternative technologies at the scale of individual buildings should mean that less water (and electricity and municipal solid waste) infrastructure needs to be provided centrally by the state or private companies to meet everyone's demands. The installation of these technologies, however, can be interpreted as an acceptance of the reduced supply by the state and normalisation of shortage (see Chapter 5). This might be accepted by the middle classes, who can increase their resilience to shortage by installing other water sources, but could actually reduce water access of the poorest residents by legitimising less state supplies water for domestic areas.

The above reasons have led the Municipal Corporation of Greater Mumbai and the Government of Maharashtra to follow the examples of Bengaluru (Bangalore) and Chennai to legislate on water supplied to new domestic buildings. Rainwater harvesting is now mandatory for new residential buildings constructed on plots over 300m^2 (BrihanMumbai Municipal Corporation, 2003, Government of Maharashtra, 2007)[11].

> "We made that it [rainwater harvesting] is compulsory for all new buildings. But why only new buildings? Why not for the old buildings? [...] because I understand that would be a constrain of space. The new buildings have a lot of space and they follow a lot of new rules and norms, which are very different from the older norms. But still you should allow anyone to do it and it should be compulsory for *everyone*." Seema Redkar, MCGM (Mumbai 20/01/2011)

However, retrofits are becoming popular through the incentives of water security and economic gains, rather than by legislation. Suprabha Marathe, the officer in charge of rainwater harvesting at the BMC, says that most of the requests for information are from residents of existing buildings looking to retrofit, rather than developers constructing new apartment buildings. Thus retrofits are an important part of the urban environmental responses, but are unlegislated.

3.6.3.4 Promoting middle class solutions to water shortage

> "It is expected that there should be an active participation of the citizens in water conservation (saving). Citizens have to generate

[11] Initially the ruling was on plots over 1000m^2 but this was amended to include smaller plots in 2007.

> water for secondary requirements through rain water harvesting or recycling." (Municpal Corporation of Greater Mumbai (MCGM), 2008: 1).

This approach to water saving in the city of Mumbai can be seen as a positive move, but it is more complex than that and could reveal an underlying attempt by the government to rollback its responsibility for water provision (as discussed in Chapter 5). The middle classes (and elites) have the financial means to secure their clean water supply, by calling for additional water tankers, digging borewells and now through rainwater harvesting. The promotion of 'green' infrastructure (such as rainwater harvesting) is a new way of prioritising the systems for the wealthy as those who can afford to fund additional sources can create their own water supply, but municipal mains water is being reduced per capita for all citizens. Many of Mumbai's residents do not have access to formal water supplies, but emphasis to address the water infrastructure deficits is being placed on self-funded decentralised supplies (McFarlane, 2008c). Thus this prioritisation of solutions to meets the needs and aspirations of the middle classes may be detracting from the important issues of the poorer residents. The right to water is a fundamental one, but it should not be confused with the right to a specific centralised water infrastructure. Thus the quality and amount of water per person should be the point of normalisation, not the method of delivery. However this still leaves open the question of cost of water and the poorest residents do not have the money or the space to install rainwater harvesting. The poorest residents of Mumbai pay the highest prices for water (Graham et al., 2013).

The prioritisation of rainwater harvesting as a response to both shortage and to the environmental issues facing Mumbai is putting the needs and wants of the middle classes before those of the poor majority, who cannot afford the capital for installing a rainwater harvesting system and may not have suitable roofs and grounds for installation. Those people living in informal settlements are likely to be most adversely affected by the rolling back of state provision, rather than the extension of it, as well as being most vulnerable to climate variability and extreme weather events. I discovered only one system for a toilet block in an informal settlement that had been funded by an international organisation, although rainwater harvesting must be included in all new buildings, such as those for rehousing of informal settlements after developments, as planned for many areas of Mumbai.

3.6.4 The illusion of one constant supply

The provision of a constant supply of water from several sources in the middle class home so that it appears to be seamlessly provided from one source is an illusion choreographed by cooperative society leaders or building managers and carried out by their employees. The rescaling of water infrastructure, or what I term domestication, to create this illusion is part of the performance of being middle class. Having a constant, sufficient of good quality water is a signifier of middle class or elite status. For many residents this is becoming increasingly difficult to maintain when per capita water provision is reduced by the municipality because of Mumbai's rapidly growing population, coupled with a changing climate and extreme weather events. Therefore many middle class residents are looking for other sources to maintain constant water supplies and rainwater harvesting becoming a popular solution.

3.7 Context for the empirical research

In this chapter I have described and defined Mumbai, and its middle classes, through housing and water infrastructure. This is not an attempt to simplify the city but rather to display the complexities inherent within these interconnected socio-technical infrastructures and demonstrate how these two key aspects interact and frame my approach to investigating rainwater harvesting. Water and housing systems both highlight political and technical systemic failures that privilege those with money or connections bringing forth issues of urban justice before the pressures of climate change are applied. Water infrastructure debates centred on Mumbai have largely focused on vulnerabilities and access of the poor and this chapter has set the context for investigating how the middle classes experience infrastructure in their domestic buildings. I use housing in particular to approach the other context dimensions and to frame this research. Mumbai's housing has become defined in the literature by its extremes and this chapter has drawn out the nature of the middle class housing between the extremes. It is this housing that forms the site of interventions explored in this research.

Greater Mumbai's geographical position on the west coast of India makes the city especially vulnerable to climate change and its peninsular location limits the available land, in turn shaping infrastructure provision and the housing market. Mumbai's administration has been shown to be tangled and often ineffectual, and this is important in my exploration of how rainwater harvesting is governed in Chapter Five. India's middle classes are heterogeneous and evolving and I have acknowledged their complexities. I use housing in this thesis to frame Mumbai's middle classes as: living in apartment buildings where the co-operative society, or management, and the residents employ servants. The city's housing is inadequate and unevenly distributed, with developments going ahead for upper and middle class residents, but affordable housing projects lagging behind. This is echoed in Mumbai's water infrastructure, which leaves many struggling to access enough water. In this chapter I have explained how the middle classes use servants to draw together several sources in their homes to create the illusion of one plentiful water supply. A major finding of this chapter is that rainwater harvesting fits into the middle class portfolio of supplies to respond to shortages of other water sources and some residents are using rainwater harvesting in their performance of class through access to services.

Mumbai's housing is the key site of enquiry for my investigations into rainwater harvesting and I use housing as a framing for the empirical chapters. The discussion of Mumbai's administration is a useful starting point for my investigation into how rainwater harvesting is governed in Chapter Five. The ways in which the middle classes secure their water resources is also key to the discussion as it moves to the rescaling of provision and governance of services to domestic buildings. The processes and configuration of rainwater harvesting are discussed in Chapter Six to investigate how rainwater harvesting is assembled. This discussion draws on the information on housing water infrastructure discussed in this chapter. The initial discussion of rainwater harvesting systems discussed in Section 3.6.3.2 is elaborated on to unpack the elements of the systems and motivations behind installation. In Chapter Seven I investigate the uses of harvested rainwater in the middle class home and in relation to other everyday practices involving water from different sources. These discussion draw upon the housing context of Mumbai and the water provision to middle class housing, and crucially the concepts of the middle class and their lifestyles presented in this chapter. In this thesis I bring together all these different threads to show why and how rainwater harvesting has taken such a prominent position as a response to water shortage and environmental change in Mumbai.

Chapter Four

Researching middle class housing in Mumbai

Figure 4.1: Another researcher walks into the frame (Source: Author)

4.1 Introduction

Carrying out research in Mumbai requires high levels of flexibility and spontaneity, and this shaped my methodological approach. Working within a different culture and the particular requirements of researching middle class housing tested this flexibility. Despite the visibility of Mumbai's centralised infrastructure, green building projects and decentralised environmental technologies can be concealed. Thus even the first step of the fieldwork, discovering sites and objects of research, became a challenge due to this hidden nature. It was through this process of discovery during initial fieldwork that rainwater harvesting emerged as a prominent technology. This chapter is used to reflect upon my exploration of methodologies and analysis techniques. This takes into account the methods selected and their strengths and weaknesses. The problems encountered and how these shaped the methodological approach are also assessed, leading to a discussion of whether research affects the city and objects of research itself.

In this chapter I justify the selection of Mumbai as the site for this study. I describe the various methods used to source case study buildings and projects, as well as those used to research them. A mixed method approach was used, focussing on interviews, site visits and photography. The data generated by each method is considered, taking into account the strengths and weaknesses of the approached used. I reflect on the challenges in researching the middle class and professionals and how this changed planned methods. I consider the interlocking issues of power, gender and safety whilst carrying out research. I also discuss wider issues in urban geography research methods and the effects research is having on cities. The high density of researchers in Mumbai led me to question the effects this may be having on my data and will be discussed from several angles to discuss what it means for the future of research in Mumbai.

4.2 Selecting a city

This research was planned as an investigation of urban responses to climate change through housing in Asia by collecting and interrogating empirical data. In this section I explain the selection of Mumbai as the case study city, beginning with the original proposal.

4.2.1 Original CASE proposal

The original proposal was for a comparative study of Mumbai and Hanoi, which could have led to a broader study that spoke to more urban centres in Asia, but I felt would spread the research too thinly within the timeframe of a PhD. The difficulties of discovering case studies in Mumbai became a defining part of the process and confirmed the change to one city. The comparative element was redefined and I decided that the emerging findings lent themselves to a single case study city approach.

This PhD has been funded through an ESRC CASE award with the Building and Social Housing Foundation, BSHF, as partners. BSHF research housing in the UK and worldwide and disseminate that knowledge. They also organise the World Habitat Awards, which celebrate best practice in housing and this expertise is reflected in the project's focus on housing as a site of response. BSHF's knowledge of the fieldwork cities and housing systems add richness to the project and this will in turn add to their knowledge base. The changing focus and objectives of this PhD research needed to be negotiated and have been embraced by BSHF. Some of the changes in the research approach can be seen by comparing copies of my research summaries[12], which I submitted for Indian research visas one year apart, particularly the change from a comparative study of two cities to a focus on Mumbai. The connection to BSHF also provides a potential dissemination pathway for the findings of this research beyond academia.

[12] In author's possession

4.2.2 Mumbai

To meet the aims of this research, I wanted to select a city that encompassed many of the challenges faced by cities in the Global South. Mumbai is a complex urban area, as discussed in Chapters Two and Three, that has an infrastructure deficit and is at risk from climate change altering weather patterns and raising sea levels. As a rapidly urbanising centre with well-documented housing issues, Mumbai is an extreme in terms of scale, housing crisis and predicted implications of climate change, but remains a useful case study for increasing understanding of responses to water shortage and environmental issues (Das, 2003, Gandy, 2009, Sharma, 2007, McFarlane, 2011). The coastal location makes Mumbai vulnerable to extreme weather events and sea-level rises (Timmerman and White, 1997). Mumbai's position as India's economic capital, and rapid urbanisation make the responses to environmental issues through housing possible. Such responses may inform changes in cities in similar contexts. Although Mumbai's status as a mega-city could be used to critique this choice, the multiplicity of the city and its networked nature open up the possibilities of knowledge transfer to other urban centres (Hodson and Marvin, 2012).

Deciding to focus on Mumbai was only the beginning as case study buildings were needed as sites of investigation. Domestic environmental infrastructure responses were uncovered mainly within the Northern and Western suburbs of Mumbai (by the methods discussed in Section 4.3), further refining the case study area. These wealthy suburbs of Bandra, Andheri, Goregoan and Powai are middle class areas interspersed with informal settlements. Bandra, which is one of the most desirable and expensive suburbs of Mumbai (Sharma, 2007), is particularly notable as eight of the seventeen sites I investigated in Mumbai are in Bandra. I also lived in Bandra for five months (see Section 7.3.1), which may have had an impact on finding examples, although the hidden characteristics of systems of rainwater harvesting and other technologies, such as solar panels (especially from street level), limited the uncovering of environmental infrastructure by merely being nearby. However, when consultants and other respondents knew where I was based, they may have suggested examples closest to me for convenience. Two of the three rainwater harvesting consultants, that I was in contact with, seemed to have work concentrated in the Bandra area, which may have brought up more examples in the area.

The first trip to Mumbai was extremely useful in focussing the research on a pivotal technology. Initially research focussed on housing and looked for any environmental initiatives including eco-housing schemes, solar water heating, renewable energy and financing systems. I realised that a common factor across all the interventions (that had been discovered) was the inclusion of rainwater harvesting. Significantly rainwater harvesting was typically installed as a first intervention, often followed by other installations. This realisation from the data focussed further enquiries and led to the hypothesis that rainwater harvesting might be important in Mumbai's transitions by opening up spaces within buildings and dialogues for other technologies. As discussed in chapters 2 and 3, water is an important resource in Mumbai and has become a logical starting point for environmental discussions in the city's media, between policy makers and within civil society organisations. This rainwater harvesting focus altered the methods by drawing attention to the infrastructure and flows through the city. The methods used for investigating and viewing infrastructure are discussed in section 4.5 below.

4.3 Discovering (hidden) interventions and contacts

A major challenge of this fieldwork was discovering projects to then research. This was a challenge due to the hidden nature of the interventions within housing, difficulties in making contacts in a cross-cultural context and the reluctance of possible contacts to engage with the research. Similar issues were faced by Weber Canon, Higginbotham and Leung (1988) when engaging professional working women to participate in their study. This reluctance can be categorised as general scepticism about the research, a lack of trust in anonymity and concern over time commitments. I used several methods to uncover interventions and build relationships with contacts both prior to the two fieldwork trips and during them. The main source of information before the first fieldwork trip was the internet, but with limited success. The Indian national and local Mumbai media, and conferences I attended in Mumbai and Delhi, proved more useful in forming contacts. The ability of rainwater harvesting consultants to open up buildings became key to gaining access and they emerged as gatekeepers. As can be seen from the discussion below, the case study buildings were largely self-selecting as those that were visible *and* accessible. See list in Appendix Two for further information about the buildings selected.

4.3.1 Web search

A web-based search was conducted from the UK and uncovered a couple of leads, including a developer that described itself as 'green' and a few members of the local authority, but few actual buildings emerged from this. This may be because a limited number of such interventions are taking place, but it may be that they are just not being documented in English on the Internet. Another reason that might prevent them from being found is that the developer, architect or resident may not think of themselves as addressing climate change, but as dealing with localised problems, such as flooding or temperature extremes, without siting these within the global context, and this changed the framing of the research. Communication with these the few leads was the next challenge as emails were often ignored and phone calls expensive. One exception was Gaurav Monga of *EcoHomes*, who responded to my emails. It became clear that it is difficult to plan before reaching India and, as a result, degree of flexibility and spontaneity is needed in the field.

4.3.2 Affiliations

To obtain a research visa for India, there must be an affiliate Indian organisation and Rachana Sansad was my affiliate during the second visit after communicating with Roshni Udyavar, Head of Environmental Architecture (Appropriate Technologies, an NGO based in Delhi, was affiliate for the first trip). Scott, Miller and Lloyd (2006) acknowledge the importance of affiliate organisations when undertaking research abroad (Vietnam in their case) as an institutional affiliation can provide connections and support. Rachana Sansad Architecture School became a useful point of contact and resource, allowing me to talk to professionals and access the school's library. Via Roshni, and her list of contacts, I was also able to conduct a survey of architects interested in environmental issues. However this did not yield any buildings for investigation, as the architects surveyed had been unable to implement what they had learned in their professional practices.

4.3.3 The media as source

Newspaper and magazine articles became very useful in sourcing buildings and professionals to research. Fernandes (2000: 619) identifies advertisements of new technologies in the media as 'visual cultural texts' that bring together national and global concepts. I found advertisements of new housing complexes in English language broadsheets (*The Times of India* and *The Hindu*) to be presented in a similar aspirational manner often drawing on imagery of 'green'[13] developments with lots of trees and vegetation surrounding them and the use of environmental terminology, however these rarely emerged as environmental projects. The middle class are becoming increasingly environmentally aware and this is reflected in the media attention that environmental concepts are gaining (Mawdsley, 2004). Coverage of international negotiations in the newspapers and special features in magazines echoes this trend.

One of my key case studies (Sealine Apartments) was discovered due to a newspaper article about the building's rainwater harvesting system. Unfortunately there were no contact details and it took me some time to track down the address, using the name of the building. This was one building to which I had to turn up at and hope to get an unsolicited interview:

[13] 'Green' is often used in the construction industry to indicate buildings that address environmental concerns, but is a broad and vague term that is often unsupported.

> The first building, the Sealine Building in Union Park, Bandra West. The building had heavy security including guards with machine guns. It turns out a minister lives there. The secretary of the society of residents in the building welcomed us into a plush office where he was already being interviewed by a student from Pune University. Navin Chandra is very enthusiastic about the retro-fitting of environmental technologies into residential buildings. He is keen to hold the Sealine building up as an example and encourage others to do the same. To this end the Union Park Residents' Association is taking over a BMC garden to be an exemplar project and teaching facility. They are also starting a community radio station to promote green ideas. He gave us a tour of the building after the interview and allowed us to take photographs.

Box 4.1: Excerpt from research diary 09/01/2010

This worked out well as another researcher was already interviewing the society secretary (this is discussed in Section 4.7.1) and so he had time set aside. I was subsequently able to visit again on several occasions. But this was an exception: just turning up at other residential buildings was usually not well received. That said, arriving unannounced at professional offices often worked well and this may be because of some of the positionality issues discussed later in this chapter. It again highlights the requirement for spontaneity and flexibility.

There were few newspaper articles featuring specific projects however and magazines were another media source that led to interviews, particularly with professionals. Profiles in special sections of magazines about homes and housing design directed me to two environmental architects and to one technology supplier. Finding informants through articles in this way had the added bonus of supplying an opener to communication, indicated that they were open to being interviewed and provided information before the interview.

4.3.4 Meetings and conferences

Meetings and conferences were important avenues for sourcing contacts as well as allowing participant observation. Fisher (2012) also describes using network events to allow participant observations, to make contacts and conduct interviews whilst conducting fieldwork in India. Attending these meetings and conferences meant that I could gain direct access to possible contacts, whom I may not have been able to source contact details for. See Appendix 3 for a list of the events I attended.

I attended a Green Rating for Integrated Habitat Assessment (GRIHA) conference in Delhi, which allowed me to hear several key figures in the debate around codes for environmental building, including the Minister for New and Renewable Energy and the Minister for Urban Development. The CTBUH (Council of Tall Buildings and Urban Habitats) World Conference 2010 was held in Mumbai and gave me the opportunity to hear and speak to several people involved in the Mumbai housing industry. The EcoHomes conference in Mumbai was largely conducted in Hindi and Marathi but still allowed me to conduct participant observation and to get a sense of the overall situation and actors involved in this governance experimentation. I also attended a local neighbourhood organization (ALM) meeting to observe participants and the processes that occur in these meetings. These events were key to meeting people and gathering data particularly on the governance of housing (see Chapter 5).

4.3.5 Rainwater harvesting consultants as 'gatekeepers'

The identification of 'gatekeepers' to facilitate access to informants and, in my case, buildings is an important part of the research process (Kitchin and Tate, 2000). The power and influence of these 'gatekeepers' in controlling and possibly limiting, contact to people and places and in positioning themselves as translators must be acknowledged and the relationship treated carefully (Desai et al., 2008, Valentine, 2005). Negotiating this relationship can be a challenge (Scott et al., 2006) but I realised early in the fieldwork that identifying gatekeepers and starting that relationship was a much greater challenge.

Rainwater harvesting consultants turned out to be central to the discovery of infrastructure installations, and were then 'gatekeepers' with access to many sites. I accompanied three different rainwater harvesting consultants on site visits to several buildings at various stages of implementation. I developed methodologies around these visits, which were particularly useful to the investigations for Chapter 6 (see 4.5.2 and 4.5.3). The rainwater harvesting consultants go beyond being 'gatekeepers' to a specific community but rather are 'gatekeepers' to buildings and projects. They bring together not just other actors (such as residents) but also the material buildings and technologies.

4.3.6 From sources to buildings

These different sources of information and places of engagement were used to form connections that led to physical sites for the research. The web search had limited results, but led to one building that included environmental measures after interviewing the developer. The affiliation enabled a survey and the interview with the Head of Environmental Architecture, who gave me the contact details of one rainwater harvesting consultant (Ajit Gokhale) who showed me round two buildings in Bandra, demonstrating some 'snowballing' of contacts. The affiliation with the architecture school also gave me invites to two conferences (Learning in Cities at Rachana Sansad, and the EcoHousing Conference and Exhibition, which had not been publically advertised). Conferences and meetings were useful for getting an overview of the building industry, to hear the views of ministers (none of whom would grant me an interview) and also the specifics of environmental rating systems. The National Conference on Green Design: Buildings and Habitats (Delhi 2011) gave me an avenue of approach to the ministries and I was able to subsequently interview an advisor (Bibek Bandyopadhy, New Delhi, 11/01/2011). The Council of Tall Buildings and Urban Habitats World Conference included a site visit to *Palais Royale* (see Appendix 2 for buildings visited during research).

The newspapers and magazines led directly to four interviews and one building (as discussed in section 4.3.3). It was Navin Chandra as gatekeeper for this building from whom I was able to 'snowball' my contacts directly through his network and showing me the Carter Road Building, where he had advised them. Crucially he also led me to two rainwater harvesting consultants (Amar Joshi and Gurjeet Singh Bedi), which translated into site visits to six separate properties.

4.4 Studying the middle classes and professionals

Prior to the initial fieldwork in Mumbai I did not know that I would be researching the middle classes specifically. Development geography suggests participatory methods (Kesby et al., 2005) and visual methodologies such as video (McEwan, 2009) to be appropriate in the Global South context to address power and language boundaries. However, middle class respondents resisted these methods. Literature on methodologies for researching the middle classes, especially in the Global South, is a gap that became apparent as I searched for an appropriate approach. Weber Cannon, Higginbotham and Leung (1988) found that the middle classes volunteered for research most readily and they needed to use more intensive methods to identify respondents from other classes within the North American context. In the modern Indian context I found the opposite to be true. Keeping a broad mind about the methods and adapting to fit the circumstances was vital. Research with the middle classes was limited to traditional methods of interviews and ethnographic observations that I had planned for professional respondents (Fernandes, 2011).

4.4.1 Planned methods

Having read literature on researching in the Global South I was eager to utilise a variety of techniques conscious of my positionality as an educated (relatively wealthy) westerner and how this might affect data collection. Original planned methods involved asking residents to complete diaries of everyday consumption practices to elicit deeper and carefully considered responses (Crang, 2005). I was also keen to use auto-photography methods as Cook and Crang (1995: 69) suggest auto-photography as a useful technique for gaining insights into how people "understand and interpret their world and themselves within it." However, with the middle classes and professionals as respondents, it rapidly became apparent that these methods would not be possible and that the power dynamic was rather different (Smith, 2006, Welch et al., 2002, Cochrane, 1998).

4.4.2 Middle class specifics

The middle class residents were mistrustful of why I would want to access their homes and then were resistant to any methods that required participation beyond being interviewed or answering a questionnaire. Another challenge was the time constraints of the respondents who I did get to talk to. Respondents understood the methodology of being interviewed and could see that it was a finite exercise, whereas something like ethnography, keeping diaries or taking photographs was considered to take too much effort. Research seemed to be understood as something done by scientific experiment in a laboratory, or at least by questionnaires and possibly interviews. Other methodologies are not taken seriously as research, being dismissed as unimportant or time consuming, and this rather limited my toolkit.

I began to wonder whether I would ever get middle class residents to talk to me, and to worry about my safety, as I was chased from a building with my research assistant (Jasmine) by a large middle aged, middle class man.

> Now there is the task of rethinking the methods to fit into an even shorter time scale. This is because, due to the response so far, I am assuming the residents want to be disturbed as little as possible. There are some problems inherent in researching the elites and middle classes.

Box 4.2: Excerpt from research diary 14/01/2010

The biggest challenge of researching middle classes in their homes was that of access, which is an issue that Smith (2006) also encountered. Even in buildings where the society secretary (who could be considered a 'gatekeeper') was enthusiastic, it was very difficult to get the other residents to engage with me. This was contrasted by a visit to a project in a slum area where a redevelopment had taken place for some of the dwellings by Triratna Prerana Mandal (TPM) and I was taken there by one of their representatives. In this situation most residents seemed eager to talk to me, invited me to look around their homes and to take photographs. The contrast in reception was startling and on the made me wonder if I was taking the difficult path by researching middle class housing. This may be because the residents are used to researchers and, instead of becoming frustrated by the process, find it interesting. The reception indicated that the residents might have found research beneficial to the community and having the TPM workers as gatekeepers opened up doors. Methods for undertaking social science research in the Global South are framed in the literature as referring to the poorest citizens. This instance demonstrated that the methods I had originally planned using current literature on research in Asia were not designed for the middle classes gave a partial view of the possibilities.

4.5 Methodologies

Crang (2005: 229) notes that research in human geography has become "methodologically more uniform", relying on interviews in particular. In this study I was keen to include other methods but limited to traditional methods, such as interviews and questionnaires by the expectations of respondents and their time constraints. However, the research of material objects of infrastructure and buildings was primarily undertaken through site visits using photographs and videos.

4.5.1 Interviews

The focus on the middle classes and professionals brought interviews to prominence as a key method to collect data to address all research questions (and especially for Chapter 5 which addresses governance). Interviews are the staple of qualitative investigations in the social sciences and were a useful method in this research (Valentine, 2005, Kitchin and Tate, 2000). Interviews are a controlled way to interact with experts and professionals to collect qualitative data. Interviews with professionals were planned as semi-structured, with questions framed for each professional. These interviews usually became unstructured as the expert expanded on their views and experiences. One notable exception to this was the MCGM officer for rainwater harvesting who limited me to one question. I took the decision to let respondents take interview conversations in the direction that interested them and this often brought up new lines of enquiry. For example in the interview with the developer Gaurav Monga (Mumbai, 16/12/2009) the conversation led to a discussion of the differences between everyday practices of living in India and North America. Another example is the MCGM Chief Engineer, Mr Kuknur (Mumbai 10/02/2011) who took the conversation away from the municipality's interventions to explain that rainwater harvesting had now been installed in his own apartment building. These two examples demonstrate the strength of allowing unstructured interviews to uncover unexpected aspects. The main weakness of the approach is that the interview can stray into irrelevant topics. Having prepared questions and a clear aim of why this respondent is being interviewed helped to direct the conversation or steer it back.

I interviewed 59 people and small groups, as tabulated in Appendix 1. Interviews lasted between 15 minutes and 2 hours, with an average of about half an hour. The majority of those interviewed are professionals (architects, NGO officers, government officials etc.) in their own offices, although three were interviewed in cafes. These were often recorded after being given consent and transcribed for analysis. However several interviewees declined being recorded due to confidentiality concerns (for example Sanjay, a developer who was uncomfortable with me taking notes at all) or because they did not think that they would have anything important to say (for example Uma Adusumilli, MMRDA Chief Planner). Even when recording was permitted I took notes and these proved invaluable in the cases where other noises, such as ceiling fans and traffic, rendered the recordings unviable. The three rainwater harvesting consultants and one of the Hiranandani Gardens engineers were interviewed during site visits and written up from field notes. I carried out three interviews via telephone, taking notes and writing them up for analysis. Some people I interviewed more than once for four reasons: some were gatekeepers to other projects (such as Navin Chandra); there was a new line of enquiry that I wanted to explore with them (for example Seema Redkar); to investigate longitudinal changes over 12 months (Nadia); and crucially to build up a relationship of trust (Roshni Udeyavar Yehuda).

Contacting and meeting with people was difficult, as discussed above, and this led to flexibility in approach. A limited level of snowballing was achieved as some of the professionals would give me details of consultants or suppliers they worked with. Building up trust was a major factor and details were sometimes not passed on until after I had met the first person several times. When asked if I could speak to someone else in the organisation/company/ministry, I was often told that I didn't need to now I had spoken to that one person. At the other end of the spectrum, one interviewee tried to send me to speak to someone else instead, and I did eventually interview the second person as well.

This dismissal of needing to speak to other people also brought out the power dynamics of knowledge and justice issues arising from assumed superiority of some respondents. I was keen to speak to servants who used water that was harvested, so that I could understand exactly what they did, whether practices had changed since installation and what their knowledge of the systems was. However, there were language barriers in speaking to them leaving me with no option but to use the 'gatekeeper' who was often also their employer as translator. This compromised results as servants might have adapted their answers to please their employers. It also meant that I was not hearing their 'true voice' and something may be altered or omitted in translation (Spivak, 1988). Employers were often unwilling to let me speak to servants because they did not consider the servants' knowledge important.

> The building secretary couldn't (after a year of explaining) grasp why I would want to talk to staff when he could explain everything and he thought watchman wouldn't know anything.

Box 4.3: Excerpt from research diary 12/02/2011

The frustration is evident in this extract from my field notes. I repeatedly met with this rhetoric of servants not knowing anything and their input to my research not being needed, and they were denied a voice by this epistemic violence (Spivak, 1988). The experiences and mundane practices of the servants are a key part of what I wanted to discover about the domestic rainwater harvesting (Briggs and Sharp, 2004). Limitations of language and not wanting to lose the hard won trust of the buildings' residents meant that I was only able to collect limited data from servants, using brief conversations and observations. I briefly interviewed one watchman (Mumbai 12/02/2011) and two maids (Mumbai 08/02/2011). The watchman gave me insights into how the building had changed over the past decade and the maids explained some of the everyday practices they undertook. This limitation informed my analysis of everyday practices in Chapter Seven, although I was also able to use observations from site visits and ethnographic methods to investigate these everyday practices.

4.5.2 Survey

I was able to use my connection with Rachana Sansad Architecture School to send a survey to architects who had studied on their environmental architecture master's degree. I collected twenty responses from what was essentially a structured written interview (see appendix 4 for template). These responses helped build an overview of the housing situation in Mumbai but did not reveal any additional buildings that might form the basis of my sample.

To many respondents it seemed a disappointment and frustration that as architects, while they are interested in environmental issues, they were not able to apply them in their design work (due to market pressures and working within established practices) and so they could not supply new projects for investigation.

4.5.3 Site visits

Buildings and infrastructure are at the centre of this research. Site visits are a common method when researching buildings and have been used by others for this purpose (Seyfang, 2008, Communities and Local Government, 2009a). They allow for the collection of technical and visual data as well as ethnographic work.

Visiting buildings, particularly when accompanied by a 'gatekeeper' (such as the rainwater harvesting consultant who had installed the system) facilitated the meeting of contacts and residents and sometimes to 'snowballing' of contacts (Kitchin and Tate, 2000). However, it was not only humans that I wanted information about and thus seeing rainwater harvesting systems *in situ* became important for learning about the material system and how it works; an ethnography of the machine.

4.5.4 Photographs and videos

Many researchers take photographs whilst on fieldwork for them to become little more than something pretty to put up when giving conference papers or to be sprinkled through the thesis. However here: "The use of photographs serves not only to question the hegemony of the written word, but also to provide an alternative to the use of language for descriptive purposes." (Dodman, 2003: 294) This follows a call for the use of more visual methodologies in human geography (Crang, 2003, Rose, 2003, McEwan, 2009). The aim of this section is to discuss the use of photography and video as data gathering. I have used photographs, videos and (collected) drawings in an attempt to understand how different rainwater harvesting systems are designed, installed and integrated into the urban fabric, in particular to answer the questions addressed in Chapter 6 around assembling rainwater harvesting. Architecture relies on visual methods for recording and presenting case studies and some of those traditions are also drawn upon. In architecture the tradition is to represent buildings through images. A building could not be designed without a visual approach. At very least an 'image' in someone's mind, but more usually detailed drawings of plans, sections and construction techniques. These drawings would be useful for understanding the buildings and getting an insight into the decision-making processes. So it seems natural that when buildings are represented in books and magazines, that they are very visual accounts.

Case studies of houses in magazines and architectural journals show photography as an important method for describing the materiality of a house. I used photography to collect data about the material systems of housing and rainwater harvesting, but also to go further to explore the processes, often through 'video field notes' I find Bollywood films (and novels) based in the city give alternative ways to view Mumbai and have attempted to engage with them as part of the background studies and as an integral part of Mumbai itself (Mazumdar, 2007, Gangar, 2003, Pendse, 2003). Mumbai is a city that lends itself to being seen through the camera.

Photographs of systems allow me to accurately recall how a system is configured, which has been invaluable to the empirical work in Chapter 6. Photographs of buildings have also helped me to situate systems and to observe practices for Chapter 7 and to compare systems with each other and with themselves over time. I carried a dSLR with me on most site visits and began by taking photographs to accompany my field notes. Later on, as site visits became more central to my methodology, I started videoing my visits as writing notes in the field was difficult and video captured so much more. Video lends itself to getting a sense of how the system flows and also allows me to capture the atmosphere, motion and sounds of the scene. These videos have been useful as detailed field notes that have kept the research fresh in my mind and allowed vignettes to be easily drawn. As technology improves I hope to continue developing the use of visual methodologies in my future research.

4.5.5 (Auto-)ethnography

I lived in three different apartments in northern and western suburbs of Mumbai during my stays in India. I used (auto)ethnographic methods to gain a deeper understanding of the ways in which the middle classes dwell and relate to their housing (Cook and Crang, 1995). This meant that it was important for me to live within apartments in the suburb areas I was studying rather than in a hostel or hotel. This auto ethnographic work gave me an insight into resource provision to flats and of the relationship between resident and residence when servants area part of the system

(Qayum and Ray, 2011, Dickey, 2000) (see Chapter 7). Employing servants during portions of my fieldwork, as also used as a methodology by Sarah Dickey (2000), was particularly useful to my understanding of domestic processes and relationships. This added to the richness of the data and helped close the distance between my own experiences and those of the Indian middle classes (McDowell, 1992, Murray, 2003). Most respondents could not see the relevance or significance of their everyday practices and so ethnographic observations allowed me to gain an understanding and to transcend language barriers. Engaging with Mumbai's middle classes in this way also helped with some of the issues of researching the middle classes by breaking down some access barriers and cultural differences.

4.6 Power and gender

Reflexivity is an important aspect of the research process. In this section I use power and gender to look at my positionality in the field as I conducted research. Firstly I discuss how the power dynamics were not what I was expecting from reading methodologies for research in the Global South. Secondly I discuss the interconnected concept of gender in these power relations. Drawing from my experiences in the field, I note how being perceived as a sexual object lead to uncomfortable situations, but also opportunities. Finally I address the safety issues that arose from my gender and lack of power whilst conducting research.

4.6.1 Power

What happens when someone spins the table of power dynamics? Much of the literature on conducting research in the Global South, stemming from feminist and post-colonial discourse, reminds the rich, educated researcher from the Global North that they must be careful not to present themselves in an intimidating way (Scott et al., 2006, Valentine, 2005, McDowell, 1992). There is a danger that through research social inequalities and power dynamics can be replicated or reinforced (Murray, 2003). Participatory methods have been developed specifically to address these issues of power and positionality (Cupples, 2002, Mohan, 2006). However, once in India I found that I was largely conducting research with highly educated, older, male professionals and this tipped the scales in the opposite direction. As a young(ish) blond woman researching Indian elites, often in their offices or homes, I was open at least to not being taken seriously and at worst to physical or sexual assault.

4.6.2 Gender

Being a female researcher in Asia has its own set of challenges: I didn’t want to be kissed or groped by people I interviewed and I certainly didn’t want to go away for the weekend with them, I just wanted to know about sustainable housing. Stereotyped preconceptions of the researcher - such as of foreign women as loose and available can be an issue. I was prepared for the extra attention in the streets especially as I am fair-haired and blue-eyed and have a habit of walking about on my own, even though I wear the most covering and baggy clothes possible, often Indian *kurtis*. Cupples (2002: 383) explains that the researcher is "sexually positioned by members of the host community". Thus I was not just positioning myself but also being positioned by those I was interviewing.

However, nothing can prepare you for when you get the wrong kind of attention in an interview. In the field I was a sexualised object - foreigner and potential sexual partner and this must be acknowledged within the methodological reflection. To get information from an interviewee it is generally understood that one should be open, friendly and polite although these shift as identity negotiations occur (Murray, 2003). But when you are a western woman it seems this attitude can be taken the wrong way. Somehow having a friendly conversation, in a formal setting, about something you are both interested in can be misconstrued as flirtatious.

> I was interviewing a manager of a development company at their offices and, although I was not allowed to record it, the interview was going well and I was getting some interesting information. At first suggestions of going to visit factories where they make solar and rainwater harvesting technologies seemed like a generous and useful offer, until told that they are on the other side of the country and we could go there and spend a few days. Some quiet alarm bells start to jangle at the back of the mind, but surely he is just trying to help to the best of his abilities. I went with a non-committal stance, until I could be more convinced of his intentions.
>
> Later in the day he calls to say he is going on a trip to his site to look round one of the residential projects he is doing and wants to know if I would like to come. Of course I'd like to see the tower! It is interesting but it is like he is showing off his building to me and showing me off to everyone else. The alarm bells are getting louder and then he suggests going away for the weekend to a beach (seriously). But I can trust him, he is very harmless etc, or so he says. Incidentally, he knows that I am not single and I was wearing a (fake) wedding ring to give me more confidence in asserting this. He tries to hold my hand several times. He wants to take photos of me. He is old enough to be my father. I get dropped off at a friend's office instead of at home so that I feel safer and can talk to them. I then ignore his calls and wonder what I did wrong.

Box 4.4: Excerpt from research diary 16/11/2009

It is a pity that someone who could have been so useful to my research should have behaved in this way and made me uncomfortable. I would have liked to speak to him professionally again and used one of the company's buildings as a case study but safety must come first and I decided to find other case studies and interviewees who know where the boundaries are, although this was a surprisingly difficult decision as it was so hard to find respondents. Cupples (2002) suggests that it is not just preconceptions that form the opinion of the researcher, but also the interactions that take place, however, a small minority of my interviewees did not seem to adhere to that. The Health and Safety protocol of always letting someone know where you are and whom you are talking to suddenly took on new relevance after this encounter. There is a reluctance to acknowledge sex and sexuality within fieldwork as it might adversely affect the credibility of the work (Cupples, 2002). However, it is an essential part of reflexivity and we cannot see ourselves as removed and separate from the object of research, and so I have attempted to present it here.

At the same time it is possible that, whilst causing some problems, my gender and position as a foreign researcher may also have literally opened doors for me, as it has for other researchers (Cupples, 2002, Scott et al., 2006). One female respondent, who had been reported by an Indian colleague to be difficult to access, responded quickly to my requests. I suspect that my unthreatening and yet out of place appearance may have made the cold calling technique that I used to get some interviews easier in male dominated offices (Scott et al., 2006). The gender of the researcher can affect the places and people that can be accessed during fieldwork, and can thus influence the research undertaken and the data collected. Domestic spaces are often female domains, making a female researcher more likely to gain access (McDowell, 1992). I hoped that being female would also help me to gain access to households (McDowell, 1992), but this did not seem to be the case.

4.6.3 Safety

During the first fieldwork trip I used research assistants recruited from a local architecture school. These assistants (one male and one female, both from Maharashtra and in their early 20s) were used to make research safer, to provide local knowledge and to translate. The positionality of any interpreters and/or research assistants is an important consideration to take into account (Scott et al., 2006). If the research assistant is badly briefed, uninterested or prejudiced against the interviewee or researcher, for any reason, it can have a serious impact on the outcomes of the research. On the second trip I decided not to employ research assistants as most respondents spoke English and gaining access to buildings and offices was difficult enough for just one person.

Having a mobile phone was a safety precaution for lone research, which I appreciated on site visits. Getting a mobile phone was vital to conducting research in India as emails are often ignored and instantaneous contact is needed. Some of the interviews that I conducted were initiated by turning up at the door of the organisation or building, as I then could not be ignored, but this can be dangerous when there is no established relationship or prior knowledge. The phone was my main method of contacting people and I even conducted some telephone interviews.

4.7 Researcher-saturated city?

Researching urban areas of the Global South has been seen as a way to interrogate the 'ordinary cities' paradigm. But are some cities now becoming new 'paradigmatic cities' and recreating past theoretical cul-de-sacs (Robinson, 2006)? Mumbai is the case study for many researchers as is evident at every conference I attend or journal I look through and this can have an effect on the way in which we consider cities and do research, but here I will argue that it also effects the city itself and those who are 'researched'. This can subsequently have a causal effect on data collection. I found myself tripping over other researchers in Mumbai and then running into multitudes of Mumbai researchers at conferences. Vignettes from my research are presented to explore how the researcher-saturation of Mumbai might affect my data collection and analysis.

4.7.1 Encountering other researchers

The seed of this section was sown whilst watching *Dhobi Ghats (Mumbai Diaries)* (2011) at a cinema in Mumbai. The story follows the intertwining experiences in Mumbai of four different characters. It gives a rich insight into lives in Mumbai and displays Mumbai's materiality to wonderful effect but it is one of the characters that started the thought process, which culminated in this section. Shai is young female non-resident Indian who has spent most of her life in America and has now returned to Mumbai on sabbatical to research traditional livelihoods (Rao, 2011). Her presence in Mumbai is also used to demonstrate India's rich culture in comparison with the materialistic West. The inclusion of a researcher as a character within popular media is important in several ways. Firstly, researchers have become such a normal occurrence that they are a natural inclusion in a film script. It seemed perfectly normal to audiences that someone would come to Mumbai to study such topics. Secondly, she made it look *easy*, which is not the experience of most urban researchers.

Mumbai is used as a case study in many research projects and, along with a few other cities, has begun to shape understanding of cities in the Global South. Robinson (2006) has led the recent turn in postcolonial urban studies towards thinking of each city as 'ordinary' and worthy of study. This has been particularly in response to the use of cities in the Global North as case studies for the understanding of all urban conditions, leading to certain paradigmatic cities (Nijman, 2000). The use of a small selection of 'exemplar' cities to understand the urban condition and theorise the city has been problematised within the urban studies literature beginning with Robinson who flagged up the issue (Robinson, 2006). However, certain cities in the Global South (such as Mumbai, Dhaka and Johannesburg) are now being intensively researched and used to describe the 'situation' in all cities in their region, thus replicating many of the issues that the new focus was striving to move away from. The intensive and incessant research of certain cities is thus problematic to the understanding and conceptualisation of cities by limiting the experiences used. In this section I focus in on the micro scale to consider what effects the number of researchers is having on the individual research project, using example from my collection of empirical data. Here I will draw on examples in to tease out the issues that arose and which could directly affect my data (as summarised in table 4.1). Firstly, unexpectedly sharing an interview with another researcher (or a group of school children) can alter the questions asked and the time you are given. Secondly some officials have rehearsed answers to what they expect you to ask, having been interviewed so much before. And thirdly one official just kept telling me to look at the website (whilst answering the questions of an entire class of school children in Marathi).

	Occurrence	Effect on data collection	Effect on analysis/writing
1	Social worker also interviewing	We were double booked. As topics were different it made it difficult to keep interview on my interests	How to acknowledge questions posed by another researcher?
2	Marketing researchers also interviewing	I knew they would be there and interviewed them a bit too. Topic was similar and it was with someone I had interviewed before	Again there is the issue of how to reference them.
3	School children also interviewing	Only got to ask one question. Children distracted interviewee and they all spoke in Marathi. Se also kept telling me to look at the website	Limited my data collection. She did however pass me onto someone else.
4	Interviewing consultant whilst he was making TV documentary (because he was busy)	Was difficult to ask questions, as he was often on camera. I could not take notes easily or record sound	Limited my collection of data but we did then visit a couple of other buildings.
5	Postgraduate researcher already there	Allowed the interview to take place	Was good for making contact with the society and I was able to visit again

Table 4.1 Encounters with other researchers

The first encounter I had with another researcher was when I shared interview slot with a researcher from a different discipline (example 1 in table 4.1). The interview was with the head of an NGO and had just begun when a European social worker turned up to interview him as well. Our research topics and objectives were very different which complicated the interview as it kept drifting off into discussions of social work and then was brought back to housing and the environment. It also meant gaining the permission from another party to be recorded and the interview lasted a lot longer than it would have if it had just been one researcher's questions. There are ethical dilemmas when it comes to using the answers to questions that were actually posed by another researcher who was also in the same interview spot. When recording was permitted I also asked the other researchers for consent, and they agreed. However, if I were to use an answer to one of the other researcher's questions, I would have to carefully consider the referencing and credit given. I have avoided this dilemma, as questions were usually not relevant to my research, except in example 2 where the interviewee (Navin Chandra, Mumbai 08/12/2010) gave his personal history of interest in the environment, which is something I had discussed with him before but not formally interviewed. I subsequently briefly interviewed the market researchers (Saatchi & Saatchi, Mumbai, 08/12/2010).

A postgraduate researcher from Pune University (India) was present in one of my first interviews (Example 5) and that was a positive experience (see also box 4.1). Early on in the first fieldtrip, after great lengths to track down an apartment block that had been featured in a newspaper article, as mentioned in section 4.3.3, I turned up unannounced with two research assistants (for safety more than anything else). There was already someone, from a university in a different state, interviewing the society secretary. In this instance it was useful as it meant that he had put aside time to be interviewed and to show her around the building and I was able to negotiate the situation for the benefit of my research. That first meeting made it possible to visit the same project several more times to establish a robust professional relationship and make more connections (see section 4.3.6), as well as see how other related projects were progressing. This instance developed an *ad hoc* mutual benefit between myself and the other researcher, who was shy in asking questions. The other researcher did however get in the way of much of the visual data collection as is seen in some of my photographic field notes (see fig 4.1).

4.7.2 Researcher-saturation's effect on data collection and analysis

The number and frequency of researchers in Mumbai can have several effects. These effects are largely on the people who are relentlessly interviewed and subsequently on the data provided by those informants. These possible effects and consequences are investigated below with reference to empirical research carried out in Mumbai. A wide range of actors were included in this research that encompassed the governance of environmental issues, the conception and installation of systems and the lived experiences of residents in the homes affected. Instances of multiple researchers in the same interview slots are the main case studies for this chapter. Interviewee fatigue could well be a problem with certain people, such as NGOs and municipal officials. It is often difficult and time consuming to set up meetings and on several occasions interview slots were shared with another researcher.

Even when there is not another researcher directly impacting on the data collection, the over exposure of key informants to the research procedure, can in turn have a negative effect on the informants' work by taking up their time. These indirect effects are applicable to anyone conducting research in highly researched areas. This fatigue can be also manifested as annoyance, presumably at the time that is consumed by interviews and possibly being asked the same questions repeatedly.

The large body of literature on Mumbai is a useful resource but it is easy to get bogged down in trying to consume and distil it all and attend all presentations on the city. This was recently demonstrated by a workshop on urban infrastructures where three of the papers focussed on Mumbai (and fourth Mumbai paper had been withdrawn) and it turned out that several people had interviewed the same people in Mumbai. It is less than six degrees of separation for the researchers of Mumbai. Another issue arising from the overuse of certain informants is that they may have answered questions so much that their answers are rehearsed. And this leads to the issue of people assuming that research is on a certain topic and not necessarily fully listening to the explanation. I often had to explain several times that I am not researching informal settlements, but middle class housing.

4.7.3 Researchers changing urban fabric and processes?

I suspect the government is aware of the rising levels of researchers. The process of obtaining a research visa seems to get increasingly difficult every year and then the visa must be registered within two weeks of arrival, putting serious pressure on the researcher to find somewhere to live (extremely difficult) as well as deal with yet more bureaucracy. The Government of India is attempting to regulate the research(er) situation and to encourage the participation of Indian researchers by requiring affiliation with an Indian institute to obtain this research visa. Most, although not all, of the other researchers I encountered were also foreigners (from Europe or the USA) and there is a hope that the academic community within Mumbai and India as a whole will start to take a more active role in researching the city. If affiliations encourage Indian institutions to take up more research and increase the impact of the research, and dissemination of the knowledge, then it is a positive initiative. However, it is another hurdle to jump and it is difficult to find a willing organisation from behind a computer in the UK. Unfortunately this is likely to backfire by encouraging people to not apply for a research visa but to enter India on a tourist visa

4.7.4 The future of Mumbai research(ers)

Researchers have become a recognisable part of Mumbai society: as demonstrated by *Dhobi Ghats* (2011). The (foreign) researcher is everywhere in Mumbai, which has led to questions concerning what effect this will have on my data, on the people I interviewed and on the city itself. There are academic researchers, documentary makers, journalists and scouts for multinational companies all circling Mumbai and falling over each other to collect data. For the individual researcher Mumbai is a rich source of data to last a lifetime/career, but is the city becoming saturated with researchers? This section is not aiming to explain why the current situation has arisen in certain cities but has explored the implications of the researchers on my data and on the city.

Mumbai is not alone in its researcher saturation but is a useful case study from which to view issues that effect much research both directly and indirectly. I am not suggesting that research in certain areas should halt but that there should be an acknowledgement of the effect on data collected. This section has demonstrated that using only a handful of case study cities as exemplars of certain urban conditions is not only problematic as a way of understanding cities (Robinson, 2006), but may also effect the cities themselves. If the people who are researched change their practices then this may impact on their decision-making. The high numbers of researchers staying for various lengths of time in a city could also cause incremental changes in the fabric of the city. The presence of researchers creates jobs for research assistants and translators as well as bringing in revenue for local businesses. It can thus change the local economy in small ways and have possible effects on the attitudes and opinions of the locals.

The number of researchers does make it easier in some respects, as it is an understood role and process (through direct access or media). If someone is interviewed regularly then they understand the research process and might be more open to it, facilitating the interview process. There are still barriers to the research process, however, even in researcher-saturated cities. The fieldwork for this thesis was with the middle classes to collect empirical data on housing issues and there was some confusion as many researchers come to Mumbai to research informal housing. Assumptions about research topic are very frustrating when respondents have pre-prepared answers. Researchers are a new wave of migrant workers into this rapidly growing city, so Mumbai might become, not 'Slumbai', but 'Researcherbai'.

4.8 Methodological conclusions

This chapter has described the methods that I used and the rationale behind the choices made. Within this I presented some of the issues I faced, not to demonstrate how they were heroically overcome but to acknowledge the difficulties of researching. I have also tackled the sensitive topic of gender within fieldwork and the unexpected power dynamics. In Section 4.7 I have also unpacked the issues arising from the number of researchers in Mumbai, to show that positionality is not created by the researcher and the researched but also by interactions with other researchers.

Flexibility and spontaneity were central to researching Mumbai’s middle class housing, thus methods changed considerably from those planned. This was largely due to the focus on middle class housing, despite the reluctance of the middle class residents to be involved in research and the rainwater harvesting angle that led to the visual methodologies used during site visits. Positionality and power dynamics were also a challenge that altered the methodologies when researching middle class and professionals in Mumbai. Professional interviews were also particularly affected by the presence of other researchers both directly in the interviews and through research fatigue of respondents.

Chapter Five

Governing rainwater harvesting

Figure 5.1 Graffiti near rainwater harvesting borewell in a Mumbai slum (Source: Author)

> "So to me, *any* initiative is good. Whether it's government, whether it's private, *any* initiative. But we should put it in the right perspective and see how appropriate it is for our country and our buildings." Brinda Somaya, Architect, Mumbai 18/11/2009

5.1 Introduction

Housing is no longer merely a shelter, or even a site of resource consumption, but also supplier of decentralised environmental infrastructure for Mumbai's middle classes. In this chapter I argue that housing is being reconceptualised as a supplier of services, especially water through rainwater harvesting, and various actors are using this new role of housing to govern service provision and therefore environment issues by proxy. This chapter is thus an exploration of how the environment is governed through housing. Firstly I introduce the concept of governance as a way of understanding the diffusion of power on environmental, water and housing issues (building on Chapter Three). Secondly I explain the new way in which housing is being orientated within the governing process, presented as a new role of housing. The three sections that follow focus on different groups of actors who govern through housing using different approaches and for different ends. In Section 5.4 the Government and public bodies are investigated, particularly looking at the laws and regulations that have been passed. Section 5.5 considers the role of builders and developers in governing housing. Green building accreditation schemes are also discussed as ways of redefining housing as tools for mitigating climate change. I discuss privately governed retrofits in Section 5.6, which shows how middle class residents are installing rainwater harvesting systems to secure resources and safeguard their lifestyles. Following these three sets of governing agents, I critique the new role of housing as normalising shortage, using the opposing 'traditional' logic of the state as water supplier. This chapter concludes by considering whether housing will begin to be supplier of other resources in the future.

5.2 Governance

The quote at the beginning of this chapter succinctly captures the actors governing in Mumbai, drawing from public and private institutions, and the need for appropriate contextual and reflexive approaches. The architect Brinda Somaya is, on the one hand, eager for any initiative put forward by any institution no matter what it is or what the motivations are but on the other hand is mindful of the importance of context-specific and appropriate solutions. In this section I explore the concept of governance as diffused control. The prioritisation of some infrastructure systems over others is then discussed within a broadly urban political ecology framework. This section aims to set up the conceptual base for the chapter to then explore the modes of governing in Mumbai and the unique role of housing through empirical data.

5.2.1 Diffused power

Governing can be described as the 'conduct of conduct' (Ekers, 2008, Li, 2007b, Rutherford, 2007, Dean, 2010). Mumbai's water infrastructure is governed by many institutions and individuals, and in this chapter I am going to show that the scale and actors involved is shifting down to the domestic building and the residents. One crucial point here is that governing is not the same as ruling and is not enacted solely by those in government through laws. In Mumbai the environment and infrastructure are governed by the government through separate parts of legislation, with an emphasis on decentralisation (Singh, 1997, Baud and Dhanalakshmi, 2007). Other non-governmental institutions and actors are then able to govern the environment within the spaces between or overlapping these. Mumbai is governed in a piecemeal way by various state and non-state institutions utilising a variety of tools (Fisher, 2012). Thus government is de-centred and institutions gain power. This does not negate the importance of government but acknowledges the importance of other forms of governing and actors, disrupting the hierarchy (Jagers and Stripple, 2003, Li, 2007a). Institutions have been a major focus of governance debates and developers (and architects) are important within the discussion in this chapter, especially the interactions between developers and government. This dispersal of influence and power makes a governance lens an appropriate way to view the situation and unpack the dynamics (Evans, 2012).

Governance is concerned with the technicalities of how governing takes place and represents a decentring of the state, leading to a more nuanced understanding of power with governing carried out by a range of actors through a variety of methods. I therefore find governance a useful concept to unpack decision-making about rainwater harvesting and the ways in which it is conducted. Governance is particularly relevant to discussions of the Indian middle classes because there is a strong civil society and relatively weak government, meaning that there is a diverse range of stakeholders participating in governing. This multiple and diffused nature of governing Mumbai's infrastructure makes governance a useful concept for investigating the how, what and who of governing rainwater harvesting in this chapter. Governance is "everyday forms of rule" (Ekers 2008: 703) or, as Karen Bakker (2010) describes traditional governance: the 'art of steering society'. Karen Bakker goes on to define governance more fully as:

> "...a process of decision making that is structured by institutions (laws, rules, norms, and customs) and shaped by ideological preferences. In the language of policy-makers, governance may be defined as the range of political, organizational, and administrative processes through which stakeholders (including citizens and interest groups) articulate their interests, exercise their legal rights, take decisions, meet their obligations, and mediate their differences." (Bakker 2010: 44)

Bakker's method of defining governance reveals the number of actors and artifacts involved in the process, and suggests that governance is a constantly changing assemblage. This is also taken up by Dean (2010: 18) who says, "There is a plurality of governing agencies and authorities, of aspects of behaviour to be governed, of norms invoked, of purposes sought, and of effects, outcomes and consequences." I consider the artifacts, tools and actors of governance to be part of wider assemblages of discursive and material elements (McCann, 2011, McFarlane, 2009). In the next chapter I consider how rainwater harvesting systems are assemblages and tools of governing are part of these assemblages. Governance is performed through an assemblage of artifacts such as laws, ideas, politicians, civil servants, residents, workers, taxes, fines and infrastructure.

Fig. 5.1 shows graffiti next to a bore well fed by harvested rainwater in a Mumbai slum. The graffiti draws on the authority of the municipal corporation in an attempt to persuade residents to 'go green'[14]. I do not know who wrote it but it has been created to influence the conduct of others and so this piece of wall has been drawn into the assemblage for governing environmental issues (McFarlane, 2009, McCann, 2011). What the image tells us more specifically is that although the municipal corporation is not the only agent of governing, its power in relation to citizens is acknowledged and drawn upon by others in their influence of others' conduct (Bakker, 2010). This is demonstrated by the inclusion of 'MCGM' (Municipal Corporation of Greater Mumbai) and 'BMC' (BrihanMumbai Municipal Corporation, the former name of the MCGM) at the top of the graffiti to reflect their power. Developed from these concepts, my definition of governing for this chapter is: to exercise authority, guide or influence the actions and/or conduct of institutions, individuals or oneself.

5.2.2 Prioritised systems

Bakker *et al* (2008) point out that the fragmented infrastructure of cities in the Global South is not merely the result of splintering urbanisms (Graham and Marvin, 2001). The highly differentiated modes of urbanisation that have taken place since the colonial era have led to uneven distribution of services that prioritises wealthy areas and residents (McFarlane, 2008a, Kooy and Bakker, 2008). The poorest residents of Mumbai struggle to access sufficient water and pay the highest prices for water from vendors (Graham et al., 2013, Gandy, 2008) (see Section 3.6). This differentiation of water

[14] Some more formal murals were observed across the city, but this is the only informal graffiti on green issues I observed (although there may have been others that I missed due to language).

supplies does two things: Firstly, it increases the number of actors with a role in governing the environment, and I argue in this chapter that some of these are those often cast as the governed. Secondly, it means that the service provided to different citizens is inconsistent. Those middle class residents with a mains connection are also those with the means to secure their water supplies by installing additional sources, such as rainwater harvesting, which are also being promoted. Thus the concerns of the middle classes are being promoted above water access for the poorest in Mumbai.

Governance is often discussed in positive terms within the neo-liberal context because the diffusion of power technically gives more power to citizens (Bakker 2010). In this chapter I critique this idea that the decentring of power is necessarily a positive change and we should not celebrate the rollback of state responsibilities. Although the diffusion of power can be beneficial to residents, it can prioritise the wants and needs of some sections of society over others. This means that governance can be used to re-enforce and legitimise the prioritisation of middle class agendas and could impact negatively on the urban poor. The prioritisation of rainwater harvesting as a response to both shortage and to the environmental issues facing Mumbai is putting the needs and wants of the middle classes before those of the poor majority, who cannot afford the capital for installing a rainwater harvesting system. Those people living in informal settlements are likely to be most adversely affected by the rolling back of state provision, rather than the extension of it, as well as being most vulnerable to climate change (Moser and Satterthwaite, 2008, Dodman and Satterthwaite, 2008).

5.3 New Role of Housing

This section considers the new role of housing as a provider of services: particularly as a water provider through rainwater harvesting. The above section discussed how governing takes place in diverse ways by distributed actors. This section considers the shifting perception of housing in Mumbai and what implication this might have for governance. This new role of housing shifts perception towards housing being a site of service provision and places housing not merely as an object to be governed but also a conduit for governing service provision and thus addressing resource shortage.

Firstly I present the traditional view of housing as a shelter and site of resource consumption. In the second section I describe the new role of housing as service provider in Mumbai. Thirdly I consider how this new role of housing presents the middle classes as resilient. The final section draws this new role of housing together with the governance ideas discussed above to view housing as a conduit for governing water supply and the environment.

5.3.1 Traditional roles of housing

The new role of housing changes perceptions of what housing is and does and so here I present the traditional roles of housing as the base on to which the new role is added. This is different from the opposing logic of water provision that calls for universal connections to a centralised system, discussed in Section 5.7. Traditionally housing is a shelter consisting of a floor walls and a roof that protects the residents from the weather and provides privacy. Shelter is not the only function of housing and several domestic practices, such as bathing and cleaning, are discussed in Chapter Seven. To undertake these everyday practices housing is supplied with resources and middle class housing in Mumbai is connected to the mains water supply and the centralised electricity network, and sometimes also piped gas. The middle classes often install additional sources to supplement or create a supply, such as sinking a borewell for additional water or bottled gas for cooking. Thus the practices inside the home make housing a key site of *consumption* of various services, but housing is now going beyond these traditional roles. What makes housing an important point of response to water (and energy) shortage is its position as a nexus of several infrastructures, allowing intervention within housing to affect several different systems. Housing is beginning to emerge as a site of resource *supply* through the domestication of infrastructure, starting with rainwater harvesting.

5.3.2 Housing as water supplier

The shift of housing from being a site of consumption to also being a supplier of services is explored in this chapter using empirical evidence, primarily concentrated on the governance of water supply. Rainwater harvesting is central to shaping this new role of housing as service supplier. In this section I discuss the logic of positioning housing as a supplier of water, particularly from the municipality's viewpoint. This is taken up again in section 5.4.2 where I discuss the implementation of mandatory rainwater harvesting legislation. From the point of view of the municipality, which is responsible for water infrastructure and provision (see Table 3.1), the addition of rainwater harvesting in one building does not just help those residents but improves water provision across the city by reducing demand and is suggested as a solution to shortage by the municipality (Municpal Corporation of Greater Mumbai (MCGM), 2008). This is discussed further in Section 5.7 where I argue that this new role of housing is normalising shortage of resources and infrastructure deficit.

The increasing density of Mumbai is putting the inadequate and poorly maintained water system under increasing strain (Gandy, 2004). Shortages of land for development in Mumbai combined with continuing urbanisation has led to a trend of redeveloping compact sites that have small apartment buildings (perhaps six storeys) to construct new high-rise apartment buildings. This has become a tactic for developers to create a profit in this dense city with little freely available, unoccupied land. The existing residents are often given a new flat within the development in exchange for the developer creating a new building and selling the other apartments on. I observed that some residents had decided to extend their existing buildings vertically by a few storeys to cash in on the same housing demand, but to minimise disruption and maximise control. Even these extended buildings are still dwarfed by the new buildings rising around them in the suburbs and inner city of Mumbai. This new verticality is putting increased strain on the infrastructure of the city, which is not being improved and extended to cope with demand (Correa, 2010, Narayanan, 2003). Although restrictions are put on new constructions to reduce demand, the housing stock that exists already strains the system by drawing large amounts of water and energy for its (usually) inefficient running. The municipality is therefore also encouraging water saving at the household level, encouraging resilience of water supply (Gandy, 2006b). This new role of housing re-scales and domesticates service provision, leading to distributed provision and power to involve more and different actors in its governance.

This new role is being framed within environmental debates by the Municipality in their plans to improve the city and achieve world class status and by advocates including rainwater harvesting consultants, environmental architects and some developers (Municpal Corporation of Greater Mumbai (MCGM), 2008, Municipal Corporation of Greater Mumbai (MCGM), 2007, Municpal Corporation of Greater Mumbai, 2009a). Rainwater harvesting can reduce the amount of water used from other sources and also reduces the energy and chemicals needed to create potable water (unnecessarily) for non-drinking purposes. The domestication of water supply makes responding to water shortages, and climate change, an everyday issue managed through domestic practices and service provision. However this domestication of response shifts the responsibility for action towards the individual citizen and rolls back the responsibilities of the state to provide vital services to all citizens.

5.3.3 Creating resilient middle classes

As housing becomes a site of supply and residents have more control over their own water sources, they also become resilient to water shortages. By resilient I mean that the middle classes can now bounce back from certain events and have the capacity to adapt to changes in water provision (Davoudi, 2012). The literature on building resilience and adaptation to resource shortage and environmental issues has largely focussed on the poorest citizens in cities of the Global South, as discussed in Section 2.5, but the middle classes are increasingly being expected to cope with shifts in resource provision.

> "It is expected that there should be an active participation of the citizens in water conservation (saving). Citizens have to generate water for secondary requirements through rain water harvesting or recycling." (Municpal Corporation of Greater Mumbai (MCGM), 2008: 1).

The Municipal Corporation of Greater Mumbai is supplying less water per capita from the centralised system than before 2008, reducing supply from 135 litres per person per day to 90 litres per person per day (Municpal Corporation of Greater Mumbai (MCGM), 2008). The MCGM expects the citizens to find their own solutions for sourcing water to supply secondary requirements, such as flushing and watering gardens (see also Appendices 5 and 6). The justifications for this are that great expense is incurred by purifying water, which is then flushed away, and the rapid urbanisation of the city (*ibid*). This is governing water practices by reducing one source and providing information about how to source water by other means, especially rainwater harvesting. Rainwater harvesting allows citizens to collect their own water and regulate its use as well as reduce localised flooding by collecting water and storing it in a tank, percolating it into the ground water[15] of rerouting it into storm drains (Pandey et al., 2003). The responsibility for water provision is thus shifted from the state to private citizens, and from the scale of the city to the building and home.

I argue that the shift of resource provision into the control of the residents of middle class buildings forms them into more resilient citizens. However, resilient middle classes and the new role of housing are co-produced and the new role of providing water (and potentially other services) would not work without the citizens having the capacity to cope. The middle classes are seeing their access to water reduced are acting to not just secure resources but to secure their middle class *lifestyle* by maintaining, or even improving, everyday practices through the use of environmental technologies. Taking control of water supply themselves gives some

[15] If the ground became water logged and prevented rainwater from draining, then this could increase flooding. However the water table in most of Mumbai has become so depleted that this would be extremely unlikely, but would be subject to surveys.

residents access to more water than before. Some upper-middle classes use this additional water to improve their lifestyles by creating a swimming pool[16] or lush gardens (as explored in Chapter Seven).

Money savings are an integral part of the motivations for installation of rainwater harvesting to secure the middle class lifestyles as water has become a valuable and scarce commodity (Smith and Ruiters, 2006). Market forces can be used to facilitate this transition towards more sustainable housing (Dewick and Miozzo, 2006). However, a barrier to the installation of retrofits is that many apartments are rented to other parties. This problem is not particular to Mumbai and can be seen in urban areas worldwide and means that the capital cost is borne by the owner but the tenants reap the savings (Sutherland, 1991). However in Mumbai, due to the co-operative run apartment buildings this can lead to further complications as some of the residents may be owners and others tenants, but systems are installed at the building scale. If rainwater is harvested for use within the building, and particularly if it replaces water delivered by tanker, then the capital costs can be recouped within a couple of years, after which the residents are saving money. This means that long-term rental residents may be willing to add to the capital because the benefits of both saving money and having more reliable access to water outweigh the initial costs. The saving would be made at the building level and could lead to a reduction in annual fees.

This creation of middle class resilience to water shortage facilitates the use of housing as a governance conduit and the diffusion of power and control. As the middle classes take up this new role of service provider through the retrofitting of rainwater harvesting systems, it allows the state to roll back provision (see Section 5.7). This recreates the uneven provision of the centralised system: by promoting middle class solutions above those of the poor.

[16]Swimming pools are becoming a popular addition to the grounds of middle class apartment buildings. These are generally outdoor unheated communal pools, except in some new build high-rises where an indoor pool may be included in the facilities.

5.4 Public governing

The new role of housing introduced above is being implemented and experienced throughout Mumbai. The government at several levels is acting to governing environmental issues using housing as a conduit. This section considers the ways in which the state, and in particular Mumbai's local authority governs environmental issues through water and housing policies. An overview of agencies and departments, and summary of policies regarding the environment, water and housing is in Chapter Three. Firstly, I begin by introducing the tools that are used, such as mandatory legislation and tax break incentives. Secondly I present rainwater harvesting legislation as a key tool that is redefining the role of housing. In the third section I discuss how this legislation is opening up space for other technologies to push through, using an extension of a socio-technical transitions framing to understand the changing legislation regime. Following this conceptualisation I present two legislative interventions that the empirical evidence points to being implemented in the near future. The first of these is mandatory solar water heating for new domestic buildings, which is set to follow easily through the rainwater harvesting aperture. The other is the use of a green building accreditation system to award tax breaks for reaching environmental standards. The potential barriers to these public governance interventions conclude this section.

5.4.1 Tools of governing

Environmental building is governed using three main types of tool: policy (such as mandatory legislation by Government); regulation (building codes, for example); and awards (such as accreditation schemes) (Halliday, 2008). These tools can also be combined, such as the ideas and standards of an award scheme being used to create new building codes. The *Eco-Housing* scheme has the potential to be implemented in this way (see Section 5.4.5). In Mumbai, the environment and climate change are just emerging as important foci for policy intervention (Revi, 2008). A policy or technology that was implemented for financial or resource security reasons may now be co-opted into environmental governance by a range of actors. This can be seen with rainwater harvesting legislation, which developed from a water infrastructure deficit but is now discussed by the municipality and environmental consultants in Mumbai as an environmental policy (Municpal Corporation of Greater Mumbai, 2009a). This retrospective branding is not necessarily a negative thing, as it shows the transition in thinking from protectionist and financial ideas towards engagement with environmental ideas, as seen through the promotion of the *EcoHousing* scheme (see Section 5.4.5). The ways in which these policies are implemented is vital however:

> "The Government just shouts!" Sanjay, developer (Mumbai, 12/11/2009)

This was the opinion of one developer of the role of government on the uptake of environmental technologies but represents some of the other professionals interviewed. This implies an approach lacking substance and also pressurising in a blanket manner but seems at odds with the ethos of the government and local authority officials who are working to encourage developers in taking up green solutions. Government agencies are important in governing through housing by creating legislation to guide industry but this works most effectively when considered in conjunction with market forces.

> "But unless you, you know, create a policy or a regulation, it's not going to happen, as much as it should right? And then in that way you'll also allow for that industry, the green industry to emerge and survive because the traditional, conservative industry is so powerful and their costs are so much lower because the scale is so much larger that you can't compete cost wise unless you allow some policy regulation to take place and energy efficiency in buildings is a big deal, it's not and it's not tough to solve, especially for a country like India because we're going to build so much more." Prathima Manohar, *The Urban Vision* (Mumbai 21/01/2011)

Shyam Balsekar (06/11/09) underlines that for developers a measure must either be made mandatory or else incentivised through tax breaks before the developers take it up seriously. This is a particular issue for new builds as the inclusion of environmental technologies, such as rainwater harvesting and solar hot water systems, can have high capital costs that are borne by the builders but the savings are passed onto the residents.

> "Once something becomes mandatory the response will be much greater [from developers]. As long as there is a choice, people will not opt for it." Shyam, *Linear Technology* (supplies environmental components to the building industry (Mumbai, 06/11/2009)

> "Government should *insist* on solar. So much construction – it should *have* to have environmental technologies. Rainwater harvesting, solar etc – not cost effective – should impose tax if not done. Individuals are not going to move on this alone, it must come from the government." Alisha, a resident in a Delhi colony (New Delhi, 11/02/2011)

When I spoke to Uma Adusumilli (24/02/2010), the Chief Planner at MMRDA, the regional plan was under revision. Climate change is having an impact on the plan but not impacting on its development. She explained that more aspects considered, the more implementation problems arise and, if climate change considerations were included, then it would be even more difficult to get the plans implemented and this is seen as a barrier to environmental issues being included within the urban plan. The chief planner goes on to explain:

> "Plan does not profess technologies, it sets down principles but allows for changes for efficiency... Plan document is city/vision/philosophy, it sets out the actions required by government to reflect the plan. Only a few are part of the spatial plan, so they [the plans] suggest other governance to meet the other objectives." Uma Adusumilli, MMRDA Chief Planner (Mumbai, 24/02/2010)

Every plan has its own philosophy and underlying concepts that frame the issues and thus influence the actions proposed. Uma Adusumilli elaborated on this by explaining the overlapping levels of the planning process in the Mumbai:

> In Maharashtra there are two types of plans; the city plans and regional plans. Urban planning is not a countrywide (federal) issue – but handled at state level. The plans are revised every 20 years maximum but you can make changes if they don't affect the character of the plan (but the plan is often violated). The regional plan is not so detailed in spatial aspects but is rather more theoretical and looks at industrial and economic development and whether to restrain or encourage cities through regulations on land use.

(From my research diary notes during interview with Uma Adusumilli, MMRDA Chief Planner (Mumbai, 24/02/2010))

The Chief Planner also described each plan for Mumbai as having a wide scope that points to other aspects requiring different governance. What the state planner highlighted in this discussion is the sheer speed of change: Mumbai has changed before the ink is dry on the plans.

5.4.2 Rainwater harvesting legislation

This is a key piece of legislation for creating the new role of housing as supplier. Rainwater harvesting is mandatory for all newly constructed domestic buildings with a plot area of over 1,000m^2 since October 2002 and over 300m^2 since June 2007 (Municpal Corporation of Greater Mumbai, 2003, Municpal Corporation of Greater Mumbai (MCGM), 2008) (also see Appendix 6). This legislation was brought in to address concerns over water shortages in Mumbai and has been retrospectively presented as an environmental policy. The environment has moved up the political agenda due to the impacts of extreme weather events and international pressures and the MCGM has included rainwater harvesting as a prominent part of the *EcoHousing* scheme (Municpal Corporation of Greater Mumbai, 2009a). It is a policy that sits between water, environment, housing and planning legislation by changing the nature of water provision and controlling development. This means that housing, and corresponding legislation, is used as a conduit to govern water provision. Developers are not granted an occupation certificate giving permission for people to live there until a rainwater harvesting system is in place and will not be connected to the mains supply without a rainwater harvesting system in place.

There is some doubt over whether rainwater harvesting legislation is being effectively enforced, as emerged in several interviews and media reports suggest that only fifty percent of new buildings have systems in place after construction (Kulkarni, 2012). This could be symptomatic of the builders not benefiting directly from installation, and so only providing the bare minimum to be within regulations. Providing additional environmental systems would create savings for the residents, but the builder would incur the costs. This is similar to the landlord/tenant barrier discussed in section 5.3.3, where the tenant would benefit from installations funded by the landlord, meaning that retrofits in rented accommodation are rare (Sutherland, 1991). The matter of checking the systems was raised with the chief engineer of MCGM who explains the process of checking rainwater harvesting systems are in place:

> "Building proposal department gives certification. This is done post construction but a licensed architect checks during the construction process."
> Mr Kuknur, MCGM Chief Engineer (Mumbai 10/02/2011)

A more detailed explanation of this was not forthcoming and leaves the implementation of the rainwater harvesting legislation in doubt.

> "To be honest, it's so easy to get around it… So even though it's mandatory on paper, erm, I think not more than 20-30% of the developers are doing it."
> Gaurav Monga, *EcoHomes* (Mumbai, 16/12/2009)

> "It's not monitored. Honestly, it's not monitored and that's where I feel that the citizens are not aware of how to do, where to do, the requirement. Many a time it starts off very well, you know if functions for 3, 4 years and then it collapses." Seema Redkar BMC (Mumbai, 20/01/2011)

Practitioners voiced concerns over whether the systems are installed and also whether they are then subsequently maintained. The issue of maintenance is a crucial one that arose in many interviews, with particular doubt as to whether it was being carried out at all.

> "There are certain mandatory things, as you know, that have come in also. But it's not enough just to make them mandatory. It is important to see how these things are implemented and maintained and after 10 years, are they done?"
> Brinda Somaya (Mumbai, 18/11/2009)

There is the question of whether there should be some obligation for follow-up monitoring of projects and whether this would be on the part of the developer, the installer, the municipality or the residents.

> "Maintenance is part of users' responsibility. We run awareness campaigns. Very important – we see ourselves as social engineers." Suprabha Marathe, MCGM Rain Water Harvesting Officer (Mumbai, 10/02/2011)

At the time of interview there was no plan to follow up the installation of rainwater harvesting to check maintenance, as it is considered an issue for private self-governing. The various processes of carrying out maintenance on a rainwater harvesting system are discussed in Chapter Six. Maintenance is a crucial part of the system

5.4.3 Creating spaces in legislation

Rainwater harvesting was the first environmental technology taken up in to legislation in Mumbai and is set to be followed by solar water heating in the near future, as discussed in the next section. The progression from one technology to another in legislation can be seen as part of transition that is occurring in Mumbai. Rainwater harvesting is creating space for other technologies to be considered (see Section 6.7 for an exploration of this concept at the individual building scale). These apertures that have been opened up in legislation are catalysts for the transition and uptake of technologies. The Ministry of New and Renewable Energy started research on solar energies in the 1980's but this was not taken up. Interest in the environment and these kinds of technologies has not been high until recently and this could be because the technologies do not address the main issues, or are at the wrong scale.

> "India needs technologies that are cheap, small and rectified for the needs of society. Simple, small things. Every house has an 'Aqua Guard' [water filter] can this be solar powered? Most people have a balcony, can they have solar lighting? Cheap and simple. Need some crisis to make everyone take notice."
> Seema Redkar, MCGM (Mumbai 14/02/2010)

The need for appropriate technologies that address not just the requirements of the population, but also the capacities and culture are required. The 20th century emphasis on large-scale centralised energy infrastructure that was developed in response to industrialisation in the Global North may not be appropriate in contemporary Mumbai where de-centralised water responses are taking centre stage. Thus South-South appropriate technology transfer might yield better results, with due attention given to site specifities. When the technology are appropriate and cost-effective solutions to the problem, such as rainwater harvesting and water shortage, a precedent is created that can be used to implement further technology interventions and legislations.

5.4.4 Solar thermal next

Legislation to make solar water heating mandatory is set to be the next intervention, continuing the transition towards environmental technologies being included in domestic buildings in Mumbai. Rainwater harvesting was made mandatory in other Indian cities prior to the policy's introduction into Mumbai's legislation. Bangalore (Bengaluru) can be seen as an indicator of the direction that Mumbai's legislation may take. Solar water heating is now incentivised in Delhi:

> "yes it is incentivised, we give subsidy. State Government give subsidy. Many of the municipalities have made them mandatory. Many of the electricity grid are giving tariff compensation. The reason is that, in our country you know, domestic tariff is less that the industrial tariff. I do not know what is in your case. So. But they have to give preferential to domestic power. Now if you use it for water heating, you are paying say 2 rupees 50 paisa per unit and if you freed that they can sell to industry at 5 rupees per unit. So they [the State Government] provide some incentive to the residential user who is putting solar heating." Dr Bibek Bandyopadhyay, Ministry of New and Renewable Energy (MNRE) (New Delhi, 11/01/2011)

Solar water heating has been made mandatory for new-build apartments in Bangalore and now for hotels in Mumbai. It is likely that the technology will be the next domestic technology to be taken up by the authorities in Mumbai as well and tied to housing law and amendments to the FSI calculations (Malaviya, 2012) . It may seem counter-intuitive that hot water would be so important in such a hot humid city as Mumbai, but hot water for showers and bucket baths is desirable, particularly in the air-conditioned home. In middle class homes, water is usually heated using an electric heater called a 'geyser', which is an inefficient way to heat the water and also causes spikes in electricity demand.

> "Yes but 23% of electricity bill is hot water and this can entirely be saved by using solar water heating. This should also be mandatory." Sanjay, developer (Mumbai, 12/11/2009)

Again the emphasis is often on the economics of technology.

> "Solar thermal is, I mean the payback is very, very quick. Investment is smaller [than photovoltaics] but the impact is very, very fast. And the energy saving is good because a lot of energy goes for heating water."… "Whereas in a solar thermal [as opposed to photovoltaics], a solar water heater, you get your money back within a year and a half." Shyam, *Linear Technology* (Mumbai 06/11/2009)

One difficulty in the implementation of solar-thermal energy is that a separate system may be required for each individual apartment to avoid conflicts over usage. In high-rise apartment blocks there may not be enough space on the roof for all the systems. The usage of the roof for the heating of water may also cause problems as many residents use the terrace as an outdoor recreational space. However the MCGM's chief engineer disagrees on the application of solar water heating in residential buildings due to costs.

> "Solar water heating is in hospitals and hotels. It is mandatory for new builds. But not feasible for residential buildings as maintenance is high and so not economical. Looked into PV for own building but price was too high." Mr Kuknur, MCGM Chief Engineer (Mumbai, 10/02/2011)

The pressures from the landscape as other cities take up environmental technologies into legislation may lead Mumbai to also implement similar policies. Power cuts to middle class apartments in Mumbai are rare at the moment, but could increase as load intensifies on the city's infrastructure.

> "When we need hot water for taking baths, you can understand it, you have electric geyser [water heater]. Now in a city like Delhi, before coming to office, all of us take baths. Here we have the habit of taking morning bath. 2kW each to the gird, multiplied by that. …last 5 [or] 6 years we have always found that there is a blackout in the morning." […] "I'm not telling 100% you can do it but even if it is 50% you shed that big load." Dr Bibek Bandyopadhyay, MNRE (New Delhi, 11/01/2011)

The demand for energy to heat water in the mornings is increasing and not being met by supply, thus Dr Bandyopadhyay sees solar-thermal water heating as a demand-side management tool. These kinds of pressures on resources for specific practices can change the nature of resource provision. These changes in resource provision are being governed through housing legislation as part of a wider strategy to address resource use.

5.4.5 Eco-Housing

The Government of Maharashtra is experimenting with other governance tools to encourage environmental housing technologies. One such tool is accreditation schemes (discussed further in Section 5.5.2), which provide guidelines or benchmarks for including environmental concepts. *Eco-Housing* has been developed by the Indian Institute for Energy Conservation (IIEC) and piloted in Pune (secondary city in Maharashtra) (Municpal Corporation of Greater Mumbai, 2009a). Incentives were offered to builders/developers for following the scheme in Pune:

> "There were some incentives like they were given 50% development charges were waived off for them. There was 50% rebate in taxes on the property taxes. And for the people who bought this also had also this challenge that it would be a higher cost flat as compared to a normal flat. They were told that… they were given lower interest rates for home loans from these particular banks." Roshni Udyavar Yehuda, *Rachana Sansad* (Mumbai, 13/02/2010)

The pilot test in Pune was successful with over 50 projects completed or with provisional certificates leading to accreditation and the programme won an award for innovation at the 2008 Asia Clean Energy Forum (Science and Technology Park, 2012a, Science and Technology Park, 2012b). Eco-housing is supported by the Municipal Corporation of Greater Mumbai and is set to be implemented as a technique for encouraging green building in Mumbai (Municpal Corporation of Greater Mumbai, 2009b). However Roshni, who helped to formulate the guidelines, goes on to highlight the problems with getting the scheme to be taken up in Mumbai:

> "No barriers. It's that we have a very corrupt (laughs) municipality. That's really the bottom line because as soon as we've finished Pune, we started

> working on Bombay [sic] and there were a lot of efforts making the layouts and the structure and everything for Bombay. We did modifications because the climate is different, the orientation and all that and it was immediately put to the municipality here and now I think it's at least 3 years. Two years that has passed and nothing has been done about it, so…" Roshni Udyavar Yehuda, *Rachana Sansad* (Mumbai, 13/02/2010)

Thus the Eco-Housing scheme is ready for implementation in Mumbai and is backed by ministers. I attended a Government of Maharashtra conference on the Eco-Housing scheme, which made it seem imminent (see Appendix 3), however at time of writing, it has not been implemented. This could be due, in part, to the Government of India commissioning and promoting a different scheme (see Section 5.5.2.2). The willingness of the state and city governments to engage with environmental housing concepts can be interpreted as an extension of the new role of housing as a service provider and conduit for governing climate change responses. Promotion of decentralised systems also begins to divest government responsibility for resource supply.

5.4.6 Barriers to public governing

The main tool of public governing is mandatory legislation, but this is hindered by difficulties of implementation. Implementation of policies in Mumbai is further complicated by a fragmented approach and corruption. Suprabha Marathe, Head of rainwater harvesting at the BMC sees the overseeing of different technologies by different departments as a barrier to policy implementation and technology uptake:

> "Solar water has been made mandatory for hostel buildings etc but is part of another department. Departments do not work together but report to one commissioner so are working together at a higher level." Suprabha Marathe, MCGM (Mumbai 10/02/2011)

Seema Redkar confirms that at the city-level the departments, just like the national government departments, also do not work together commenting, "we all work separately". However she is happy to work across departments and to ask the state government if she needs something and sees networking as lacking and needs to be worked on which could lead to a change in approach. This lack of coherency is a problem at the national level too.

> "Ministers like to keep their turf separate. The GOM (group of ministers) then the EGOM (empowered group of ministers) will meet but really it is the Committee of Secretaries that actually run everything – it is they who make the cross-cutting bridges." Prof. Saugata Roy, Minister of State for Urban Development. Speaking at the National Conference on Green Design: Buildings and Habitats (New Delhi, 08/01/2011)

Thus a more integrated approach to environmental governance might lead to more effective implementation of legislation. Powerful developers can also stand in the way of public governing (see Section 5.5.1).

5.5 Governing by developers, builders and institutions

The de-centring of government brings other institutions to prominence and increases social control. Non-state actors and institutions are vital in governing housing in Mumbai.

> "Lots of time is taken, and lots of money is made by companies and consultants. At the city scale a response is needed [by the administration]." Uma Addusumilli, The Chief Planner of Mumbai, MMRDA (Mumbai, 24/02/2010)

Developers are making a lot of money by marketing new properties as green developments to attract higher prices from buyers and environmental consultants are making money by advising these developers and residents. The local authorities want to be a part of the 'green' building market and to control this activity by powerful companies. One of the main ways that builders and institutions are influencing environmental transition in housing provision is through accreditation schemes.

This section begins with an introduction to the key actors in this institutional governing: builders and accreditation bodies. In section two I site this within the housing market, that was introduced in Chapter Three, to demonstrate how closely linked this is to the methods and tools used by institutions to govern. This further explored by looking at two accreditation schemes that are used by developers in India. This leads to a discussion of builders and the government working together, particularly using these assessment schemes to encourage and regulate environmental measures in the construction industry. Finally the relationship between corruption and governing is explored.

5.5.1 Builders and developers[17]

Developers are key actors in governing new build apartment blocks. In Mumbai the realty market is such an important industry and developers can be extremely powerful. The clearing of land to build new apartment buildings is controversial but has been undertaken for the gain of the developers for years. The influence of the developers on the property market and on the way in which new buildings are constructed means that they are central to the transition of the technologies and the focus of many policies and assessment schemes. The housing market in Mumbai is closely related to the tools which builders use to govern. The complex and highly pressured housing and land market in Mumbai was discussed in Section 3.5.3.

For developers, profit is the driver of their activities and the government regulates this through the Floor Space Index (FSI). The FSI dictates how high a building can be on a certain plot of land, and how much money can be made, it can thus be used by the government to manipulate the market and incentivise certain building practices. My survey of architects in the Mumbai area pointed to money and the FSI as the central focus of housing in Mumbai. This focus on profit can lead to corruption and mafia involvement in the construction industry (Das, 2003, Gandy, 2009). As Gandy (2009: 15) says "Where land is not made readily available to developers it can be acquired through corruption, intimidation…". Corruption is a serious issue in India and is a major problem Mumbai's construction industry and in the drinking water sector (Asthana, 2008, Bakker, 2010). This leads to problems of access and affordability of both housing and water. Developers may pay

[17] Developers are often referred to as builders in India and the terms are used here interchangeably, as they were in interviews.

bribes to influence planning decisions or the mafia may be involved in coercion for similar monetary gains through the construction industry.

It emerged from the empirical study that individuals in development companies can be central to implementation by changing the ethos of the company or just by promoting the use of one technology. Only a few developers agreed to interviews, due to a lack of interest in environmental issues or driven by a concern for keeping their current projects and methods secret from their competitors. From the limited sample, I observed that it was one individual who is driving the environmental innovations, often after being educated abroad. EcoHomes adopted rainwater harvesting, and installed it in EcoDale, before legislation under the guidance of one of its members:

> "So the first building he [interviewee's father] did, it was called 'EcoHomes'. At that time it was just a concept that he wanted to incorporate eco-friendly features in it and, you know, start a new brand of eco-friendly buildings. It wasn't heard of at that time, in India especially. So the first building he didn't do too much. I think he did rainwater harvesting and a couple of other small things. Nothing major. But it is only when I came back - I was studying in America for 2 years – I did my masters there in construction management and I did some research on eco-housing in that, so when I came back we did a couple of projects where we tried to implement a lot of stuff." Gaurav Monga, *Eco Homes* (Mumbai, 16/12/2009)

An individual in the company brought the inspiration to undertake environmental building and then others supplied the knowledge. Although the inspiration came from an individual it must be noted that the uptake of ideas into the structures was only possible due to the network of actors and so credit cannot be taken by one person alone (de Laet and Mol, 2000). It clearly took many years to develop the environmental building concepts in the company. EcoHomes had hoped to continue to include more environmental features but found no market for such residences. Their website still proclaims them to be environmentally friendly but with no substance to back up the branding.

> "…Otherwise it's just been for the name to be honest. We always planned that we will do it in a big way and we've just been looking for the right kind of land to build on. We have finally zeroed in on a large project and we will be starting in about 6 months' time. So that's going to be, you know, a much larger area, almost 100 acres and this is on the out skirts of Bombay. We are calling it '*EcoCity*'." Gaurav Monga, *EcoHomes* (Mumbai, 16/12/2009)

This kind of green wash is common but it seems that there is an emerging market for sustainable residences, meaning that *EcoCity* can go ahead and shows that the scale of ambition has also increased. In new builds the motivation is often unclear and shrouded by builders' publicity. Many development companies make environmental claims but, even after site visits, I couldn't determine any particularly environmental credentials in some. This could be seen as green-wash to fill a niche perceived in the market, to get the flats in the buildings sold.

Corruption is a problem in India and was highlighted by the protests against corruption led by Anna Hazare (India Against Corruption (IAC), 2010). This perhaps highlights the mistrust of the state felt by the middle classes and could be seen as an additional spur for the governance beyond the state. Corruption itself is a difficult and delicate subject to bring up in interviews but was touched upon by some interviewees. Amar Joshi points at how the desire for power can be turned to his advantage:

> "you really just have to bribe the right people, then your project will sail through. These reports rarely get accepted the first time, as officials want to show their power, so it makes sense to make some obvious mistakes early on so those will get corrected and the details won't be looked into!" Amar Joshi, geologist and rainwater harvesting consultant (Mumbai, 25/01/2011)

Corruption is one mode by which corporations and individuals have been able to influence governance or side step the rules themselves and the middle classes may also be involved. The backlash against corruption also demonstrates the power of the middle classes to mobilise around an issue and influence the governance landscape.

Builders and developers in Mumbai are influential, notwithstanding ties with the mafia and municipality, due to their wealth through prices of land and the lucrative real estate market. This gives builders some power to influence or resist change and one way in which they are changing housing provision is through development of a market for environmental buildings.

5.5.2 Accreditation schemes

Green building accreditation schemes are voluntary systems designed to encourage and acknowledge green building measures (Halliday, 2008). These schemes are concerned not only with energy and water conservation, but also provision through rainwater harvesting and renewable energy. In this way accreditation schemes are reinforcing and extending the new role of housing as service provider. These schemes were originally private enterprises, but are being increasingly taken up by governments (see Table 5.1). Accreditation and rating schemes are not without controversy and are often seen as money-making opportunities:

> "Well let's say that, as I said, the rating systems have been used by corporates to create a brand for themselves." Roshni Udyavar Yehuda, *Rachana Sansad* (Mumbai, 13/02/2010)

This cynical attitude towards rating systems was supported by other architects and professionals. In my survey of architects I asked what affect these schemes are having in Mumbai (see Appendix 4) and received a range of responses varied in opinion and detail:

> "My experience is that the developer community seems to have been interested in getting such certification only to promote their projects and to increase its marketability or saleability. Majority of the projects which are recently certified through these certifications seem to have incorporated the green design principles or green technologies not from the conceptual stage (which is desirable or is the right approach) but much later after realising its benefit only from marketability point of view, hence becoming most of the times an afterthought. There seems to be not much concern for the environment, co-relation between the environment, building and its occupants, but majorly for the saleability of the project." (Respondent 16, Question4)

> "Minimal" (Respondent 2, Survey Question 4)
>
> "They have been imposing certain Parameters but are yet not made mandatory, hence it does not create a great effect on the industry. People who are aware are using the preferred technologies but most of them have not bothered to even look into it." (Respondent 13, Question 4)
>
> "It is good to start with but these are again at a building level and not at community level." (Respondent 18, Question 4)

The general opinion from the twenty respondents is that anything that raises the profile of the green building agenda is good (see also the quote at the beginning of this chapter), but the pathway is becoming narrowed and at the same time used for commercial gains without truly embracing the supposed ethos (Indian Realty News News, 2nd May, 2009). Following the guidelines for an accreditation scheme is usually rewarded either with and accolade or, sometimes, monetary incentives, such as tax breaks.

This section looks at two green building certification schemes that are used to govern the environment through housing in Mumbai. The first is LEED (Leadership in Energy and Environmental Design) which was first developed in the USA for commercial properties but has since been adapted to create LEED (India) by the Indian Green Building Council (IGBC) and applied to residential buildings. The second scheme is the GRIHA (Green Rating for Integrated Habitat Assessment[18]), which was developed specifically for India to work with all its climatic zones by TERI (The Energy and Resources Institute) and the MNRE (Ministry of New and Renewable Energy) placing it as the preferred schemes of the Government of India. Despite its prominent position, GRIHA has had limited uptake across India and so its limited success as a governance tool is considered here. A third scheme is *Eco-housing* (as discussed in Section 5.4.5) that has been proposed for implementation by local government.

[18] Griha is also a Hindi word meaning 'house', which gives the acronym an extra layer of meaning

Scheme	Institution(s)	Model	Incentives	Mumbai Buildings
LEED (India) International	IGBC (developed from USGBC)	Points awarded for each technology Awards up to platinum	Internationally recognised award	Palais Royale
GRIHA National	TERI MNRE	Holistic approach that starts early in the process	-	Hindustan Unilever Ltd
Eco-housing Local	IIEC (USAID) MCGM	Points for responses. Locally developed and housing only	Tax-breaks	Piloted in Pune and about to go live in Mumbai (?)

Table 5.1: Green building accreditation schemes in Mumbai

5.5.2.1 LEED: successful international scheme that promotes green building

LEED (Leadership in Energy and Environmental Design) is a world-renowned accreditation scheme and a special version of the code has been developed for India. LEED India is based on the original LEED (that was developed in America by the United States Green Building Council) and is co-ordinated by the Indian Green Building Council. Points are awarded for inclusion of different technologies and the total number of points dictates the level of award (up to platinum) (United States Green Building Council (USGBC), 2011). In India, the most famous building to be awarded a LEED certification is the CII building in Hyderabad (housing the Indian Green Building Council), which attained LEED Platinum in 2003. LEED India has become a popular rating system for industrial buildings, used by Indian and multinational companies to show their commitment to the environment. The system is beginning to be applied to domestic buildings in India, and is a way to get an edge over competing developers.

Shorey (at TERI) sees the LEED system as having an agenda of promoting American technologies and so not necessarily the best technologies appropriate for the location:

> "LEED doesn't work for India, not even LEED India works for India." Gaurav Shorey, TERI (New Delhi, 30/12/2009)

The accreditation scheme has been critiqued for the methods of assessment, the way in which the score is weighted and the focus on the material building and not on the processes and building life-cycle (Humbert et al., 2007). LEED has also come under criticism for prioritising technological fixes and not acknowledging passive techniques (see Section 5.5.2.2). Ratings systems have their shortcomings as governance tools, which was picked up my several respondents (especially architects):

> "So you know you may not have any water efficiency in your building but you will still get a gold rating. OK? That is how it is. And there are so many… not exactly loopholes but flexible ways by which you can get things. You know? In a place like Mumbai, for example, every place is near to a public transport system so that point is said and done." Roshni Udyavar Yehuda, *Rachana Sansad* (Mumbai 13/02/2010)

Palais Royale, an apartment building being constructed in Mumbai*,* has provisional LEED Platinum accreditation and is proclaiming itself as India's first 'green' residential building, signalling a trend change in construction. Amar Joshi (rainwater harvesting consultant who is now working on India Tower, which aiming for Gold LEED rating) believes that no (residential) project in India would be capable of achieving Platinum rating. *Palais Royale* was under construction when I visited and the main impression was of concrete, but the atrium, which is set to be the tallest in any residential building, was beginning to emerge[19]. This atrium allows some natural ventilation to be possible across what would otherwise be a very deep floor plate however the amount of daylight provided from the atrium cannot be high. There is renewed interest in this kind of vernacular eco-building in Mumbai but there are many disconnects when attempting to apply this to high-rise buildings in dense urban context (Correa, 2010). The site visit to *Palais Royale* revealed it to be constructed from large amounts of concrete,

[19] The atrium was part of an attempt to apply *Vastu Shastra* to a high-rise building. *Vastu Shastra* is a set of Hindu design principles and guidelines for constructing buildings. The suggestions lead to buildings that are naturally ventilated and created from local materials and so can lead to designs for vernacular eco-housing.

which is allowable in the scheme that puts little emphasis on construction materials (10 points out of 110), and where points can be made up by the addition of other technologies.

This scheme has been used here to explore the use of global standards and international influence on building design. LEED is influential in its branding in a way that promotes itself but also the concept of green building globally and has a direct link to the creation of schemes in India.

5.5.2.2 GRIHA: a national scheme with limited success

GRIHA (Green Rating for Integrated Habitat Assessment) was developed by TERI (The Energy and Resources Institute) and the MNRE (Ministry of New and Renewable Energy) developed specifically for Indian contexts in contrast to the LEED system. GRIHA also has a holistic approach to the whole site, beginning early in the design process, to consider passive technologies and not only add on technologies.

> "LEED is also a very good rating system, but if you see the concept of LEED it is essentially for the energy conservation and energy efficiency. So what in GRIHA what we tried to do, we incorporated that solar passive thing, along with energy efficiency and energy conservation and an introduction of renewable energies. Things like solar water heater, PVs, whatever. And to give a rating system. That's the difference between LEED and GRIHA." Dr Bibek Bandyopadhyay (MNRE), (New Delhi, 11/01/2011)

The top priorities of this system are power and water, applied differently in all the climatic zones of India. Materials are becoming an increasingly important concern, and so is the third priority. Currently many construction materials are imported from China and GRIHA promotes the use of local materials, which would also benefit the economy. GRIHA works on a benchmark system but the benchmarks are absolute levels, rather than set at a percentage of what an 'average building' would use (see Halliday 2008). For example there is an amount of energy consumption that a building cannot cross but that absolute value varies with climatic zone (Mumbai being warm and humid). GRIHA has been taken up as the national scheme by the Government of India. The Ministry for New and Renewable energy is now working on how to roll out the scheme and encourage developers to use it.

> "… first we are trying with sweet words and we are also keeping ourselves ready to give them tools and guidelines and regulations and manpower. You need also qualified architects to do the thing. So we are doing capacity building. All these things we are doing after some time we will say that you *have* to do it, that the government regulation is this, but we are going step by step. Right now we are giving incentive, that if you follow it we'll give you this tax concession. We'll give you this, we'll give you that, and after some time we can always tell them now it is mandatory." Dr Bibek Bandyopadhyay (MNRE), (New Delhi, 11/01/2011)

This is a succinct description of how the national government sees the transition to GRIHA becoming an industry standard might occur through creating niches and encouraging the market, before taking it up into legislation. Shri Deepak Gupta (MNRE) at the GRIHA conference is looking for ways to take the GRIHA concept forward. The scheme is in its early stages and so only 500 people have been trained in GRIHA and 100 assessors. A handbook is being released and self-evaluation is a concept being considered as a way to encourage participation. Shri Gupta suggests concessions in tax for efficient buildings and putting into architecture school syllabuses. GRIHA is only for new buildings as the holistic approach would make it difficult to apply retrospectively but could be for old buildings, if they can prove soil and tree preservation, then they are happy to give GRIHA accreditation.

5.5.3 Government and builders working together

Bulkeley and Schroeder (2011) suggest we need to look beyond the state/non-state divides and this is borne out in the empirical data, which demonstrates the overlapping of roles and the ways in which different institutions affect the practices of each other. Developers and consultancy firms are key institutions that are part of the governance of housing, but individuals are becoming increasingly powerful (particularly in retrofits).

> "Government schemes should be green but unless private sector comes in on this the effect is not enough. If this takes off, we will revolutionise power in

> India." Dr Farooq Abdullah, Minister of New and Renewable Energy. Speaking at the National Conference on Green Design: Buildings and Habitats (New Delhi, 08/01/2011)

Dr Farooq Abdullah (Minister of New and Renewable Energy) outlined the importance of using a governance approach, as the Government cannot achieve this kind of transition alone. This again shows the willingness of Government officials to share environmental governance with other institutions.

> "No it was minister called some prominent developers of the country. It was a dinner meeting. Minister told, see these people have come out with this thing, we have not made it mandatory so far. Why don't you volunteer it? Because you are making so many buildings so many things are being done by you from the private sector, these are the papers, these are the things, guidelines, these are the incentives we will give you. Why don't you do it?" Dr Bibek Bandyopadhyay (MNRE), (New Delhi, 11/01/2011)

Dr Bandyopadhyay, an aide to Dr Abdullah, explains that the minister is acting upon this by trying to persuade key developers to become first movers. This meeting shows that the minister is managing a niche in which the adoption of green building technologies would be protected and is keen to use the markets and work with developers to govern the direction of house building in India. The Government is looking to the developers to take the responsibility and govern. Governments and builders are powerful in India, and working together could have a marked effect on environmental governing through housing.

> "But I always say that we have to convert them [politicians] because if the politicians and the builders really believe in this only *then* is there going to be change. Which is not going to be enough for people like me, we are too small, and even as a group we don't have enough of a voice so change has to come from the people who govern and the people who have power." Brinda Somaya, architect (Mumbai 18/11/2009)

Governing is all about who has the power: how this is negotiated and enacted. Brinda Somaya does not see how the individual can make a big difference or govern, but the next section looks at just that: how private residents can govern retrofits effectively. The new role of housing explored in this chapter places individuals and communities in new positions to govern their resources.

5.6 Privately governed retrofits

Rainwater harvesting is the key example of a retrofit technology within this thesis, due to its prominence in Mumbai. The apartment buildings considered in this research are run as private co-operatives and often linked together in Advanced Locality Management groups (ALMs) and this section explores how buildings and areas are privately governed through these systems.

Retrofits of environmental technology, such as rainwater harvesting, are privately negotiated and governed, and so it is these instances that are considered in this section. Retrofits are encountered individually as they are privately embedded within the residential buildings, and can be individually governed. The question here is whether retrofits into existing buildings can be co-ordinated and governed collectively. This exploration begins with an explanation of the governance structure of co-operative housing, in particular the ways in which new environmental technologies are negotiated and installed. The ALMs that provide wider civil society influence are then discussed through their roles in governing and links to the local authority.

5.6.1 Co-operative housing

Middle class housing in Mumbai is usually managed as private co-operative housing groups. These housing societies are sometimes members of and regulated by the National Co-operative Housing Foundation of India (National Housing Cooperative Foundation of India (NHCF), 2012). In new-build-high rise apartments this is becoming less prevalent as a way of managing buildings but is still prevalent amongst the established middle classes. For the retrofitting of a technology, such as rainwater harvesting, it may be that all the residents have to agree. This can be a difficult situation as one individual may not see the benefits or even just want to exert his or her own power within the building (Adiga, 2011). Depending on the constitution of the building it may only need a percentage to agree and the money could also come from the annual co-operative membership fees. As Alisha in Delhi said of the situation in her colony of residential buildings:

> "Not everyone gave money. Don't need whole society to agree as it doesn't affect them directly. It is beneficial." Alisha, Delhi resident (New Delhi, 11/01/2011)

This hints at the potential to install without having to get permission if the work is to take place in the grounds and has little impact on the residents and their homes directly. The water in this scheme was only to be used for cleaning and maintenance of the communal grounds surrounding the building, and rainwater is used for outdoor practices (as discussed in Chapter Seven). One co-operative society president at a different building went further in a scheme that was about to start on site by using the annually collected fees to carry out the work and thus negate the need to collect funds. Whether everyone must agree or not, the drive often comes from one individual champion within the scheme (as discussed in Section 5.6.3).

5.6.2 ALMs: Civil society groups concerned with the environment

Advanced Locality Management groups (ALMs) are local societies formed from groups of co-operative housing societies that join together and liaise with the municipality through special channels to discuss local issues including: keeping local environments clean and healthy; and regulating behaviour towards the environment (as discussed in section 3.4.3). There are lots of ALMs but not all buildings are part of an ALM. Many of the issues that are raised relate to environmental concerns. There has been a movement from focus on one issue to incorporating other environmental concepts.

> "I always said 'why waste management? Can you go something beyond? Can we go in for rainwater?' so they [the local group] went in for rain. 'Can we go

> in for solar?' None of them went in for solar so far." Seema Redcar, MCGM (Mumbai 20/01/2011)

Thus Seema Redkar sees solid waste management as the first focus of Advanced Locality Management (ALMs), followed by rainwater harvesting, and this can also be seen as the start of a transition. The ALMs now consider several environmental concepts for implementation.

> "The ALM is basically focussing on 4 or 5 issues. One is rain: recharging ground water and rainwater harvesting. Composting, encouraging composting and separation of waste. Recycling of dry waste. Through the waste pickers. Then we are not very strong in solar but we intend to start that. In addition to that, people have gone into a lot of small initiatives at the local level like tree plantation. Greenery, patches of green… Where there are citizens' organisations like the ALMs." Seema Redkar, MCGM (in charge of ALMs), (Mumbai 20/01/2011)

> Residents come together to form a group. Then register with local authority. Starting with waste management with the separation of waste streams. She goes on to explain ALMs are usually 1 or 2 lanes or about 15 buildings. (Union Park Residents' Association is about 50 buildings) they simply register with the BMC. Bharati Kakkad, Union Park Residents' Association (Mumbai, 02/12/2010)

These groups work in partnership with the municipality and could influence policies in their favour (Anjaria, 2009). It is the middle class residents of specific buildings in certain areas that constitute an ALM and thus only one section of society's views are promoted (ibid.). It is not just the poor citizens who are not part of these groups, but the elites at the other extreme are also absent:

> "few elites. They rarely interact. There are elites but not many. The middle and upper-middle classes." Seema Redkar, MCGM (Mumbai, 20/01/2011)

Seema Redkar points out that elites are very busy and also have managers to sort out many things at home, leading to the issues that arise from a separation between residents and practices in the home as discussed in Chapter Seven. Seema also points out that many of the ALMs are run by senior citizens who have time and this is was also seen in the meeting. The senior citizen focus of the ALM is an interesting contrast to the younger generations who are seen by others as being more aware of environmental issues.

I attended an ALM area meeting that drew together several ALMs with the aim of re-engaging the groups with the core values of waste management and the local environment. However the meeting was co-opted by people complaining about encroachment and demanding slum removal from their areas, as this was a chance to be directly heard by representatives from the MCGM. These ALMs give additional power to the middle class residents of an area to control who has access to the area and for what purpose (Anjaria, 2009, Baviskar, 2011, Mawdsley et al., 2009). Uma Adusumilli points to 'NIMBYism' (Not In My Back Yard) and thinks the response should be at city level. She goes on to comment that the smells and health issues (etc) of pollution is a hook by which to encourage change not to endanger the microclimate.

> "We have a dynamic BMC and ALM here. Bandra[20] is lucky. People here see that things get done. It has had two international awards for participation. And two awards for slum work." Seema Redkar, MCGM (Mumbai, during ALM meeting 11/12/2010)

Originally meetings were once a month but then once in two months at BMC office. These ALM groups were tailing off, but now representatives are coming together to revive the ALMs. Mawdsley (2004: 81) explains how middle class presence in public debate, through channels such as ALMs, can be enough to influence and affect environmental governance:

> "…the middle classes exert a disproportionate influence in shaping the terms of public debate on environmental issues through their strong representation in the media, politics, scientific establishment, NGOs, bureaucracy, environmental institutions and the legal system."

[20] Bandra is a suburb in North West Mumbai.

The position and agency of the middle classes gives them access to and influence on institutions involved in the governance of housing and the environment. Thus neighbourhood associations such as ALMs facilitate the promotion of middle class priorities through connections to the municipality (Zérah, 2007, Anjaria, 2009).

5.6.3 Individual champions

Alisha, a female Delhi resident, who played a central role in getting rainwater harvesting retrofitted in her colony, explains one problem in getting everyone to agree and how education plays a central role:

> "When we were collecting money, it was hard to explain to people in our generation, hard for them to understand. People were unwilling to pay but their kids understood. Schools and education are key. But all these things take time." Aisha, resident (New Delhi, 11/01/2011)

A lack of understanding can lead to one person standing in the way of new technology, such as a rainwater harvesting system but she makes the point that knowledge about 'green' technologies is divided generationally. Some societies have got around getting everyone to agree by only using the water for outdoor purposes thus not needing intervention in members' homes and using money from the annual subscription. The power dynamics within a building can become destructive, as described in media and literature (Adiga, 2011), but often hidden within buildings. This building-level governance structure can lead to working together for change but can also be a challenge.

> "In most of the cases, it's the residents. Whether they have implemented it or not, it is the residents that come forward. And especially it is one resident who is aware of it and then they build up momentum in their society. And then usually we have done, I don't know how many presentations to residential housing societies. We go there and show them what is rainwater harvesting and why and how it will benefit them." Roshni Udyavar Yehuda, Head of Department of Environmental Architecture at *Rachana Sansad* (Mumbai 13/02/2010)

Thus after one resident has the idea and approaches consultants the dissemination of the idea is taken forward. This highlights the confidence of residents and hints at the power of the cooperative society model for governing buildings but also that the spark often comes from just one resident who lights the fire of interest in the others. This initial spark of interest can be interpreted as the first moment and artefact of the assemblage (see Section 6.3). In the *Sealine Apartment Building* it was the society secretary, Navin Chandra, who has spearheaded the environmental infrastructure provision. He has then gone on to influence others to install rainwater harvesting through consultation and media channels, and was a founding member of *Jago Mumbai* who have now created an eco-garden (see Section 6.7.1 and http://jagomumbai.in/). His motivation was environmental concerns coupled with a desire to secure water supplies but he used economic arguments to convince the other residents. This is an example of the power of individual motivation.

The influence of the individual was also brought out in discussion with Dr Gokhale (a water saving consultant) concerning the rainwater harvesting and grey water recycling system he had installed at *Kanti Apartments*. The previous cooperative society secretary had driven the project, but has since passed away. Dr Gokhale thinks it is now very unlikely that any other environmental technologies will be install at *Kanti Apartments* without that one man's influence.

Individual influence can have negative impacts in the longer term. Seema Redkar of the BMC goes further to describe how a new society secretary will sometimes undo the work of the previous one so that they can make their own mark on the society and show how influential they are.

> "…I mean it [system in a particular building] has won the national award for its work as one of the best activities but once that award came in and that person got recognition, because it was an individual, the whole society then objected to it. And they stopped; they don't want all this. This is something we don't find in other countries." Seema Redcar, MCGM (Mumbai, 20/01/2011)

Each society president or secretary wants to leave their mark and increase their importance. However this situation quoted above, also highlight the problems that can arise from publicity.

5.6.4 The media and publicity

The media have huge influence over their audience and thus have power over policy by proxy. Environmental debates have been increasingly reported in Indian newspapers (Fernandes, 2000, Mawdsley, 2004). During the two years in which fieldwork was carried out the levels of media interest in the environment was observed to be quite high (especially on issues of water saving and alternative energy supplies), with discussion reaching a peak around the COP 15 talks in Copenhagen. The developers also use the media to their advantage to promote new buildings and 'eco' or 'green' and this was seen in the papers and discussed in interviews.

> "I was reading in the papers the other day about some builders who are coming out with some of these things [environmental rhetoric]. I think they are realising, and there's a good middle class today in India who are quite vocal, so people want to be seen [to be 'green'], some people just use it as a selling point." Brinda Somaya, Architect (Mumbai 18/11/2009)

This highlights both the role of the media in disseminating ideas and the power of the middle classes in shaping housing provision. However there was a consensus from many stakeholders that the adverts from the developers are greenwash, showing green areas, in an attempt to cash in on this new environmental awareness. The Indian middle classes are becoming increasingly environmentally aware through media exposure and the highly networked nature of this globalised era. Mawdsley (2004: 82) advises caution in embracing this new environmental emphasis however: "Critically, these indications of a growing 'environmental' consciousness are not necessarily positive — either for environmental improvement (however that might be defined) or for the poor." Environmental causes are sometimes pursued in a selfish manner to protect the areas, interests and lifestyles of those with power. This has led to a bourgeois environmentalist attitude as described above, although this seems to be changing to some extent, we must not become blasé because the environment may emerge as merely a trend that does not lead to tangible results. The quote that began this chapter (from a well-known Mumbai architect) declares that any environmental initiative is good, wherever or whomsoever it comes from, as long as it is in context, but she does not go on to say whether the motivation for action is important. Publicity and education can work together to promote environmental ideas.

> "So there were a lot of, apart from the academic curriculum, we did a lot of other activities involving people in rainwater harvesting campaigns, solid waste management, building materials, seminars and a lot of other things. Now I guess all this built a momentum which led for people to think that environmental architecture is important." Roshni Udyavar Yehuda, *Rachana Sansad*, (Mumbai, 13/02/2010)

Information about the technologies and campaigning for uptake is useful in increasing awareness. Getting publicity for a specific scheme, however, can be a double-edged sword:

> "Actually it starts with a group of people but one of the people will be working on that because the remaining people may drop off later. As I said, if it is very well recognised, if it gets a lot of publicity, then it becomes a pain, a pain in the neck. But if it is low profile, and it's maintained then it continues." Seema Redkar, MCGM (Mumbai 20/01/2011)

Publicity can have a snowballing effect and encourage and educate residents of other complexes about retrofitting rainwater harvesting, and other technologies. However, the above quote points out that this same exposure to public gaze can create tensions within the original scheme and may explain some of the reluctance of residents to participate in this research (see Section 4.4.2). This kind of publicity helps the business of installation companies and increase responses to environmental issues, but it can also be an invasion of privacy and so demonstration projects are rare.

5.6.5 The Government and retrofits

Seema Redkar of the MCGM agrees that more involvement from the government is needed in retrofits and asks an important question about the different ways in which new and old buildings are governed:

> "We made that it [rainwater harvesting] is compulsory for all new buildings. But why only new buildings? Why not for the old buildings? [...] because I understand that would be a constrain of space. The new buildings have a lot of space and they follow a lot of new rules and norms, which are very different from the older norms. But still you should allow anyone to do it and it should be compulsory for *everyone*." Seema Redkar, MCGM (Mumbai 20/01/2011)

To install a legal retrofit the government has a role in approving and monitoring installations, particularly those that have a bore well as part of the design. To install a bore well at a property a geological survey must be undertaken, this will be discussed further in the next chapter as part of the initial discursive assemblage of rainwater harvesting, but here the role of government officials in the process should be discussed. Suprabha Marathe who is in charge of rainwater harvesting at the BMC says that most of the requests for information are from residents of existing buildings looking to retrofit, rather than developers constructing new apartment buildings.

This demand for information about retrofitting could be higher than for new-builds because the developers have access to information through other channels and have experts and consultants on hand, meaning the local authority takes on different roles for them. Also a developer will create many buildings, but only require the basic information on installing a rainwater harvesting system once, or even access this by proxy through the rainwater harvesting consultant. The role of the rainwater harvesting consultant becomes pivotal to the process for both the new build and the retrofit. Both types of building must have systems that are appropriate for the site and specifics of the construction and needs of the residents, and at the same time to adhere to the rules and regulations set out by the authorities. The role of the local authorities, and government generally, seems limited within retrofits at first. Certainly it would be easy for small-scale retrofit projects to go undetected and thus unmonitored by the BMC.

> "We visit, check the water requirement and geology leading to the design of a basic scheme that is most suitable." Suprabha Marathe, MCGM (Mumbai 10/02/2011)

Rainwater harvesting consultants also supply knowledge and expertise to residents for retrofit projects. The rainwater harvesting consultants who advise on many projects could be central to any further governance intervention, perhaps in the monitoring or mapping of retrofits. Prathima Manohar suggested that the retrofits might be governable using a longitudinal model that has been used in Germany:

> "I mean retrofit, if you create the right policy environment, you can if you incentivise companies to be interested in retrofitting people's homes for free and take equity in long term savings. That's a big deal, but it requires policy push." Prathima Manohar, *The Urban Vision* (Mumbai 21/01/2011)

The municipality may have to become more involved in encouraging and supporting retrofit projects, if they are to become widespread. Rolling back state provision and supplying information on alternative sources such as rainwater harvesting (see Appendices 5 and 6) may not be enough to secure the new role of housing as there are several perceived barriers to the retrofitting of rainwater harvesting systems in Mumbai. Firstly there is the high capital cost, although the savings on water means that the costs are recouped quickly. Secondly, within a cooperative society everyone must agree. Lastly, in older buildings the infrastructure is well established and flats may have been reconfigured. However, the differentiation of supply facilitates the installation of extensive rainwater harvesting systems for specific purposes.

5.6.6 Extreme privatisation?

The interaction of providers and users of environmental services is important and good links can lead to accountability in decision-making (Baud and Dhanalakshmi, 2007). But what happens when the providers and users of those environmental services are the same people and places? The new role of housing, which I have identified in this chapter, has led individual citizens to have more control over their water supply. This shifts governance debates from the interactions of institutions, to a focus on individuals within buildings.

This rescaling of power through privatisation and diffused governance of water infrastructure has been undertaken in many cities, such as Erik Swyngedouw's (2004) analysis of Guayaquil. However, in Mumbai the scale of privatisation is different because it is mobilised at the scale of the individual building so that suppliers and consumers are the same actors. This rescaling gives them greater control over their supply through this extreme form of privatisation down to the micro/building scale, as part of the new role of housing. The governed and the governors have, in effect, become one and the same.

5.7 The opposing logic of water provision

In this section I critique the new role of housing, as a provider of services and mitigator of environmental change, laid out above, as normalising water shortage and shifting the emphasis from the state to developers and residents as responsible for water supply (and in time other services?). This critique begins by introducing the dominant opposing logic that water and other vital services should be supplied (or guaranteed) by the state. In section two I argue that the new role of housing normalises water shortage and co-produces the resilient middle classes discussed in Section 5.3.3. The normalisation of water shortage changes the responsibilities of the state in supplying water. This section concludes by considering the justice implications of prioritising systems that are unaffordable for much of the population whilst not extending state provision on environmental grounds.

5.7.1 State as service provider

Much of the urban infrastructure literature that refers to Mumbai focuses on the poor citizens and their (lack of) access to water (Graham and Marvin, 2001, Gandy, 2008), and is linked to debates of sanitation and drainage deficit (Gandy, 2006b, McFarlane, 2008b). Access to water and sanitation is a basic human right and academic debates have rightly focussed on water access for the poorest residents of the city, who do not have the funds or capacity to install alternative infrastructures. There is pressure on the municipality to extend and improve the centralised piped supplies. There should be adequate good quality water supplied to all citizens but the positioning of the state as sole supplier of water and reliance on the centralised network as the solution is linked to the traditional understanding of housing as a site of resource consumption, discussed in Section 5.3.1. The poorest residents of Mumbai pay the highest prices for water (Graham et al., 2013). The prioritisation of rainwater harvesting as a response to both shortage and to the environmental issues facing Mumbai is putting the needs and wants of the middle classes before those of the poor majority, who cannot afford the capital for installing a rainwater harvesting system. Those people living in informal settlements are likely to be most adversely affected by any rolling back of state provision, rather than the extension of it, as well as being most vulnerable to extreme weather events associated with climate change. However, the extension of centralised infrastructure is expensive and disruptive, leading to inaction by the municipality, and a potential rolling back of state responsibility for provision (McFarlane, 2008c).

5.7.2 Water justice and normalised shortage

The water infrastructure deficit is experienced by all Mumbai residents but water infrastructure is highly differentiated and uneven across Mumbai, as discussed in Chapter Three. Both national and local governments are positioning environmental housing as part of the solution to ease demand on the centralised system.

> "Green buildings also need rainwater harvesting and water recycling. Green buildings reduce costs, not just for residents but also for city level." Prof. Saugata Roy, Minister of State for Urban Development. Speaking at the National Conference on Green Design: Buildings and Habitats (New Delhi, 08/01/2011)

The addition of rainwater harvesting in one building does not just help those residents but improves water provision across the city by reducing demand and is suggested as a solution to shortage by the municipality (Municpal Corporation of Greater Mumbai (MCGM), 2008). The provision of these alternative technologies means that less water, electricity and municipal solid waste infrastructure needs to be provided centrally by the state or private companies. The installation of these technologies, however, is an acceptance of the reduced supply by the state and normalisation of shortage. This might be accepted by the middle classes, who can increase their resilience to shortage by installing other water sources, but could reduce water access of the poorest residents.

The middle classes (and elites) have the financial means to secure their clean water supply, by calling for additional water tankers (see Section 3.6 and fig. 2.1), digging borewells and now through rainwater harvesting. This new role of housing is a new way of prioritising the systems for the wealthy as those who can afford to fund additional sources can create their own water supply, but municipal water is being cut for all citizens. Many of Mumbai's residents do not have access to formal water supplies, but emphasis to address the water infrastructure deficits is being placed on self-funded rainwater harvesting systems (McFarlane, 2008c). The right to water is a fundamental one. The quality and amount of water per person should be the point of normalisation, not the method of delivery, and so a diversity of supply can be a positive thing leading to increased water security for more residents. However this still leaves open the question of cost of water and the poorest residents do not have the money or the space to install rainwater harvesting.

There is potential for rainwater harvesting retrofits in informal settlements but they would even more complicated than retrofits to middle class apartment buildings. The first complication is that rainwater is generally collected from roofs and open spaces, and this may not be practical in a slum area. I discovered only one rainwater harvesting system in an informal settlement (next to the graffiti pictured in fig. 5.1). The rainwater harvesting scheme in an informal settlement in Santa Cruz (North Mumbai) was undertaken by a community-based origination called Triratna Prerana Mandal (TPM) (Alfred Herrhausen Gesellschaft). Rainwater is collected water from the outdoor play area and the roof of the community centre that TPM constructed. This water is now used to flush the public toilets at the centre. This shows the potential for much needed rainwater harvesting schemes in informal settlements, but there may not be space. There is also the issue of funding schemes and of political will. In Mumbai the municipality is reluctant to supply informal settlements with infrastructure as this could legitimise the area (Graham et al.). Decentralised systems could help bridge the infrastructure deficit but current focus is on middle class responses that are self-funded, reinforcing the uneven water distribution (Swyngedouw, 2006). In my opinion, it does not matter whether infrastructure is monolithic centralised systems or dispersed decentralised systems as long as it is built, maintained and provides resources to all citizens.

5.8 Conclusions

Housing is being re-cast as a provider of services, primarily of water through rainwater harvesting interventions. This chapter has shown that this new role of housing is being enacted and reinforced through governance practices by the state, private institutions and private citizens. The new role positions housing as a conduit through which to govern infrastructure and resource provision.

The state is reinforcing this new role of housing through rainwater harvesting legislation. I have argued in this chapter that a new role of housing is allowing the state to redefine its role as service provider, and roll back its responsibility for universal provision. The creation and implementation of rainwater harvesting legislation has been shown to have potential for leading to other technologies being written into legislation, starting with solar water heating. In this chapter, the experimentation with assessment schemes has demonstrated further will in the public sector to encourage responses to environmental issues through housing.

For the developers the new role of housing means that they are required to install additional systems into their new building projects, giving them extra responsibilities. Some builders are opting to use accreditation schemes that consider not just water supply but also energy systems in a bid to increase sales. Most private developers require incentives or legislation from the state before installing environmental infrastructure. Evidence suggests that some developers are not installing effective mandatory systems.

The use of eco-rating systems to control and direct the way in which building becomes environmental blurs the state/non-state boundaries (Bulkeley and Schroeder, 2011). The combined effect of green building schemes is to raise the profile of environmental buildings and move the concept towards the mainstream. This fits within the new role of housing as a provider of services by encouraging the construction of buildings that collect water and create electricity from renewable sources on site. These schemes present one possible trajectory for transition to more sustainable housing forms, giving power to the companies that devise and run them to shape and direct infrastructure. The state is experimenting with assessment schemes to encourage and shape locally appropriate responses themselves. The use of these schemes by government at different levels is creating protected niches in which environmentally sensitive housing can be constructed and compete with the current standard practice. Environmental schemes are also beginning to be seen as aspirational by middle class residents.

Private middle class residents are working to the same understanding of housing to secure their water supply by retrofitting rainwater harvesting systems. The new role of housing has thus co-produced middle classes that are resilient to water shortage and to some aspects of climate change. By accepting this new role of housing the middle classes normalise the shortage of municipal water supplies, drawing on the capacity of the resilient middle classes to address the infrastructure deficit and prioritising their supply over poorer communities. Retrofits are important within the new role of housing as service provider presented in this chapter due to their role in creating resilience and forming a new level of privatisation. As the middle classes collect and supply their own water they form a new type of localised privatisation, which feeds back into legislation.

Chapter Six

Assembling rainwater harvesting

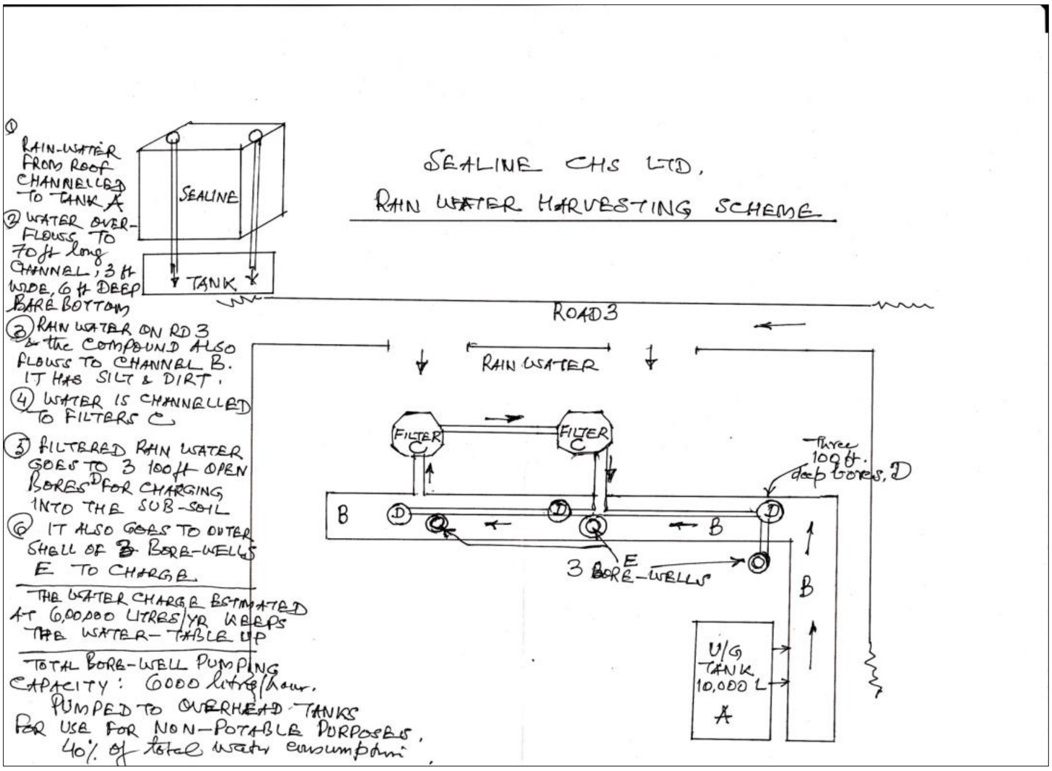

Figure 6.1: Rainwater harvesting scheme (Source: Navin Chandra, Sealine Co-operative Housing Society Ltd)

6.1 Introduction

Rainwater harvesting infrastructure is assembled from many heterogeneous components. This chapter interrogates rainwater harvesting's role as infrastructure in buildings and the city through the processes of installation and provision. An assemblage approach is used to understand the process of installing and maintaining rainwater harvesting systems. Concepts of assemblage enable interrogation of the heterogeneous elements that are drawn together and the emergent properties of the rainwater harvesting systems (see Section 2.4). Systems at different stages of the process are variously described with an analysis of how they relate together and change over time. The narrative of this chapter takes a broadly chronological order that follows the assembling of rainwater harvesting from inception and installation through to utilisation and ongoing maintenance. This temporal structure is to display the vitality of rainwater harvesting, and all infrastructures, as processes rather than static systems. To analyse the empirical data through an assemblage lens, snap shots of different rainwater harvesting assemblages are presented. These are freeze frames at one time and place in the process to show different configurations and moments, not of stability, but moments of transition.

Snapshots of assemblages at four stages in several different buildings are explored through the empirical data to interrogate the process and changes in the heterogeneous elements. These snap shots, when viewed together aid the understanding of changing assemblages. Firstly the inception and motivations for the installation are discussed using a range of case studies. Secondly I consider the design of systems, including the role of geologists, consultants, technology salespeople and architects. The third stage is the physical installation of the rainwater harvesting system, which brings into the assemblage new sets of actants, including the material systems of pipes and pumps, and temporary actants such as labourers. The fourth stage is the seemingly most stable, but it is here that I particularly consider change through maintenance. The dis-assembly and re-assembly during routine maintenance can create incremental changes, as can tinkering to make improvements and I argue that the exclusion of certain elements from the assemblage alters the composition of the assemblage.

Assemblages are often regarded as changing in a rather haphazard, incremental manner (McFarlane, 2011, Farías and Bender, 2010). However, my empirical investigation underpinning this thesis also found that change in an assemblage can occur in a systematic and directional way in some of the case study buildings, after the installation of rainwater harvesting. Subsequent installation of decentralised infrastructure was observed and reinforces the new role of housing as resource supplier leading to resilient middle classes. It is suggested that some aspects of the socio-technical transitions approach can be used to conceptualise these directional changes towards more sustainable domestic buildings in which rainwater harvesting acts as a catalyst.

6.2 Rainwater harvesting as assemblage

An assemblage lens allows infrastructure to be considered as a process created through the emergent properties of elements. An assemblage approach to rainwater harvesting systems thus considers how the individual heterogeneous elements, both discursive (surveys, plans, legislation) and material (pipes, valves, mosquitoes), are brought together to form the emergent properties of the assemblage. Using an assemblage approach to discuss the design, installation and maintenance of rainwater harvesting systems in this chapter reveals the changes that happen during these processes. Moments of translation between discursive and material elements occur throughout the design and installation stages. The assemblage also changes through processes of dis-assembling and re-assembling, especially during maintenance (McFarlane, 2009, Graham and Thrift, 2007). The stability (or territorialisation) of the rainwater harvesting assemblage also shifts constantly as components change throughout installation, maintenance and the seasons.

There are many different approaches to the installation and use of rainwater harvesting technology, from the relatively simple guiding of storm water down a sloping drive into a tank to sophisticated systems on terraces and in gardens leading to the re-charging of the groundwater that feeds a borewell.

> "There is a misconception that rainwater is collected in a tank and used, but how big can a tank be? And where in Mumbai is there space? In a small degree it is done like this but it is not the answer. We must fill the tank nature has provided. The water table goes down and needs to be replenished. So charged into soil." Navin Chandra, Sealine Apartments (Mumbai, 09/01/2010)

The variety and richness of approach, and use of this technology, in Mumbai makes it particularly pertinent for understanding the complexities of the home and city as assemblages as well as wider urban socio-technical transitions. This section considers the ideas and concepts of rainwater harvesting systems and the drawings, legislations and permissions that form part of the assemblage.

The analysis in this chapter is also informed by the methods used to collect data, which involved taking photographs of different stages of systems during site visits. Videos (of digging wells and maintenance for example) are also useful here as extremely detailed field notes from which I have brought out the interconnectedness and the materiality of the system through vignettes to explain the systems in detail.

Stage of process	Key elements	
	Retrofit	New build
1. Idea/motivation	Co-op secretary Resident Water shortage	Legislation Architect/builder
2. Surveys	Geologist RWH consultant Building	Geologist RWH consultant Site
3. Permissions	Municipality RWH consultant Surveys and forms	Municipality RWH consultant Surveys and forms
4. Design	RWH consultant Residents Existing building & grounds	RWH consultant Architect/Builder Site
5. Digging	RWH consultant Workmen by hand	Builders By machine or hand
6. Installation	RWH consultant Workmen	Builders and plumbers
7. Post installation		Checked by municipality and given certificate for occupation
8. Maintenance	Watchman RWH consultant's employees	Building management Some follow up from builder

Table 6.1: Stages of assembling rainwater harvesting

Extensive water cuts, including restriction of supply to new housing, and concurrent legislation to make rainwater harvesting mandatory in Mumbai's new-builds are forcing developers to act and residents are also taking up the issues by retrofitting systems and thus two broad categories of intervention are the new build and the retrofit. There are dichotomies between retrofitted systems and new-builds due to the elements involved (material systems and buildings, governance, people, maintenance etc), shown to some extent in Table 6.1 and is also reflected in rainwater harvesting systems installed (see Section 6.4.2). There is also a difference of scale, as most new builds are considerably larger than existing buildings, and this has an effect on the material systems, the process and on the number of actants involved. The ways in which these different systems are delivered and experienced is a key point of comparison.

6.3 Planning rainwater harvesting

This section unpacks the inspiration and reasons of a range of actants for installing rainwater harvesting systems. There are often multiple layers of reasoning and there is an attempt below to acknowledge this and to critique the stated reasons. Individual motivation has emerged as a key factor driving specific installations and can be motivation from a member of a co-operative society to retrofit rainwater harvesting or the drive of an individual within a development company/architecture firm to push for more environmental standards including water management (as discussed in Chapter Five). Three things motivate the retrofitting of rainwater harvesting systems by middle class residents: a desire to secure their lifestyles; the economic benefits of supplying their own water; and to build resilience to extreme weather events. Importantly, environmental motivations are largely absent from these discussions (with some exceptions), and often mentioned by residents as only a secondary motivation in conversation with rainwater harvesting consultants. For the builders and architects the motivations are different. Builders require mandatory legislation or incentives to incorporate environmental services in their buildings, however some architects argue that buildings and the environment are entangled and designs should reflect this.

6.3.1 Middle classes' response to shortage: securing lifestyle

Rainwater harvesting has emerged as a pivotal environmental infrastructure technology in Mumbai, correlating with unreliable monsoons and a rise in environmental awareness amongst the middle classes (discussed in Chapter Three). The municipality and Government of Maharashtra suggest that rainwater harvesting is a solution to water shortage but present it using imagery and language of environmental issues (see Appendix 6 for example). The emergence of rainwater harvesting in Indian cities, and the uptake into legislation for new constructions, is a reaction to this unreliability and the difficulty in securing the water supply for a rapidly increasing population. The catastrophic Mumbai flood of 2005 was followed by poor monsoons in subsequent years, exacerbating water shortages, demonstrating the disruptive agency of water (Revi, 2008). This led many residents to secure their own water supply by retrofitting rainwater harvesting, which also reduces localised flood-risk. Water shortage is a daily issue that can have serious implications for the urban poor. The middle classes are also affected by small daily infrastructure disruptions (see Section 3.6) and are reacting to these constant irritations.

Environmental stresses affect all Mumbai's residents, however, this section concentrates on those middle classes that installed rainwater harvesting in their domestic buildings (whilst often employing informal dwellers as servants to clean cars/clothes and water gardens with rainwater, as discussed in Chapter Seven). Increasing shortages are inspiring the middle classes to provide themselves with greater resilience and lifestyle security and this can mean installing rainwater harvesting, supporting the new role of housing. This reaction to increased shortage acknowledges the agency of nature.

6.3.2 Economic costs and benefits of rainwater harvesting

One economic issue is that the capital cost of installing rainwater harvesting is borne by the developer but the residents reap the benefits and savings (see Section 5.3.3). This is underlined by my survey of architects who were extremely cynical about the motivations for building in Mumbai, almost unanimously declaring money to be the driving force of the city's development. Developers have themselves declared that they need either incentives such as tax breaks or legal requirements, such as mandatory legislation to persuade them to take up environmental technologies (see Chapter Five). In commercial buildings eco-rating is more likely to encourage environmental buildings:

> "Ah but in residential, no, and for that to happen, there have to be incentives, given by the Government so that if, you know, if you do eco-friendly housing, your property taxes will be lower and your maintenance will be easier and all of that." Gaurav Monga, *EcoHomes* (Mumbai, 16/12/2009)

Thus for environmental technologies to be taken up by developers and built into new residential buildings they need to either be mandatory (such as rainwater harvesting) or give monetary benefits to the developer, such as tax breaks (see Section 5.4.1). However Section 6.5.4 highlights the cost benefits of installing rainwater harvesting to provide water for the construction process.

Economic reasons are cited by residents for the installation of rainwater harvesting, especially in buildings that were relying heavily on tankers to reinforce their water supply before. The capital costs may be high but the savings quickly add up.

> "People take these environmental technologies as a cost, but it is not a cost. It's an investment". Navin Chandra, Sealine Apartments (Mumbai, 09/01/2010)

For retrofits the economic arguments are strong in favour of installing rainwater harvesting. In Section 7.4.6, Mr Kuknur (Mumbai, 10/02/2011) explains how using rainwater to flush toilets has reduced his buildings water bill and paid for itself in two years. The economic viability of these installations makes them attractive to residents and can encourage further installations. It appears that the person who instigates an installation may have environmental motivations (see Section 5.6.3) but then persuades other residents using economic and resource security arguments.

6.3.3 The agency of flows

Water demonstrates its power to influence and change lives through events such as floods and droughts, which are then constructed as catastrophes and water shortages (Swyngedouw, 2004). The disruptive agency of water can encourage the idea of installing rainwater harvesting amongst residents and policy makers, and is often the driver for installation of rainwater harvesting into existing buildings. Disasters, such as the floods of 2005, are strong demonstrations of this disruptive agency and bring to light inadequacies and mismanagement (as discussed in Section 3.2.2), but water also disrupts in more subtle way. Droughts, and water shortages exacerbated by them, also drive changes, so that the very absence of water has power. Water shortages lead to an increase in water scarcity (and thus also in prices) and they also lead to residents relying on other sources of water, such as tankers (see Section 3.6.2 and fig. 2.1). Tankers, however, are expensive and rainwater harvesting is seen as an attractive alternative. The way in which resource provision and infrastructure are lagging behind the construction of new apartment buildings has become a concern for Charles Correa, one of Mumbai's most respected architects. Correa recently called for a halt to Mumbai's high-rise buildings until sufficient infrastructure is in place (Correa, 2010). The installation of rainwater harvesting can help to alleviate the pressures created by new buildings, but may not be enough.

The agency of water is important in rainwater harvesting systems and the desire to control nature has led to a mismanagement of water resources in Mumbai. The natural environment is another part of the assemblage and the recharging of water to the ground has a beneficial impact on the local biosphere.

> "Actually we are only drawing water, we are not giving water [by using basic borewells or municipal supplied water]. So by this [rainwater harvesting] we are doing recharging so it also being drainage will come and the trees will get the water. It's good that we are doing one kind of nature protection, helping the natures to grow. Greenery." Osmosis Assistant, rainwater harvesting consultant (Mumbai, 24/01/2011)

Rainwater harvesting can thus not just benefit the people in the assemblage but also plants and wildlife and increases water available to other areas of the city, by reducing pressure on the water supply. The water table is retreating as ground water is used up, without recharging it with rainwater. Rainwater that is not collected flows out to sea and become saline. Due to Mumbai's coastal location, if the fresh groundwater is used up in an area then seawater moves in. Salt is an unwanted component in the rainwater harvesting assemblage. The encroachment of salt in the assemblage makes the water unsuitable for cleaning and watering plants (as well as non-potable) thus negating the purpose of harvesting the water and rendering the rainwater harvesting system not-fit for purpose (de Laet and Mol, 2000 discuss similar issues with bush pumps). If the borewell becomes contaminated by encroaching seawater, then recharging with rainwater may not be enough. Mr Singh further underlines the difficulties in creating an assemblage that includes a borewell:

> "Down, down, down, level is going down. So that's why we have done now 700 feet borewells. 600 feet, 700 feet in the area of Powai – Andheri/Powai area. We have done 700 ft borewell but it didn't get water. There is no single drop of water." Gurjeet Singh Bedi, *Osmosis* (Mumbai, 24/01/2011)

Water is becoming harder to draw, even in areas next to lakes, such as in Powai. The power relationships within the assemblage are complicated, uneven and changing. Salt encroachment and over-extraction of ground water have changed the balance of power. The metabolism of the city has been disrupted and the flows are impeded. The use of buildings to collect and supply water, through the new role of housing as service provider (discussed in Chapter Five), could reverse the metabolism pathway by recharging water into the groundwater system.

Several water systems are part of each building's assemblage to increase resilience and new ways are being found to increase the water supplies to keep up with demand. Water has a vital role in the assemblage, which changes through the yearly cycle in this monsoonal region. When water was stretched further by light monsoons many residents took action to secure their own supplies by retrofitting rainwater harvesting systems to fill the gap in provision and reduce flood risk. This decentralised infrastructure reinforces the new role of housing introduced in the previous chapter. This gives control of resource supply to the residents and builds the middle classes as a resilient group towards environmental stresses, particularly water shortage. The water shortages are present all year round, with mains water only supplied a few hours a day and stored in tanks and supplemented by borewells and tankers, with each source supplying a different range of processes. This differentiation of supply facilitates the installation of rainwater harvesting into existing buildings.

Water security is a central reason that rainwater harvesting is installed by residents. This is a factor closely related to costs as water shortages can drive up the cost of water (especially if tankers are called in to cope with the shortage). This individual motivation is sometimes due to environmental reasons, such as for Navin Chandra the co-operative secretary of the *Sealine Building* and Garauv Monger, a developer from *EcoHomes*. But in other instances the environmental rationale is revealed to be a veneer later applied over economic and resource security concerns by residents talking to researchers or neighbours. When reasons are presented as environmental for new-build constructions they may merely be green wash or astro-turfing by developers as an angle to sell properties. The combination of economic and resource shortage motivations leads me to conclude that it is the middle class lifestyle that is being secured.

6.3.4 Traditional architects' viewpoint: design and environment entwined

The four well-established Indian architects who I interviewed, have all been designing environmental architecture for decades do not see the separation between design and the environment. Those interviewed spoke of a more holistic approach considering the whole system as part of the environmental design:

> "So, for me, the way an architect designs, in a country like India, always had to be sustainable. It was never an option and I don't think that you build a big glass and aluminium box and then you air condition it and then you decide that is fulfils eco-sensitive requirements" Brinda Somaya, Somaya and Kalappa Architects (Mumbai, 18/11/2009)

These architects are considering the building as a whole assemblage of parts that work together, rather than adding additional parts, as the developers seem to conceptualise the process of creating an 'eco-building'.

> "India is a country that needs shade, as you know. So how do you bring in shade: Though courtyards, whether it's through pergolas or sun-breakers or whether it's through using water as a micro-climate, whether there's planted trees and the right kind of trees, in the right places. These are all the things that bring in a sensitivity and then of course the second thing is that water is always going to be a big issue in India. So how do we ensure that water is… that the groundwater is recharged? That we don't allow water to run off the site and that we sustain sort of preserve it on the site so it recharges the soil and these are some of the basic things" Brinda Somaya, *Somaya and Kalappa Architects* (Mumbai, 18/11/2009)

Design is a complicated process and the design of infrastructure processes, such as rainwater harvesting, is lent further complexity by the context and number of actants involved (Williamson et al., 2003). The building itself has agency and the building's structure and position may dictate the system design though this will depend on whether a holistic or add-on approach is taken. The positioning of other infrastructures will also impact on the provision of new water infrastructure in the building and the city as a whole. It appears that the mature architects in Mumbai often see these issues as integral (also see the work of Charles Correa). Younger architects may be coming round to this way of thinking as most architecture schools in Mumbai now offer environmental teaching, but there are still problems in getting the ideas across:

> "…we went from government offices to schools and colleges explaining what environmental architecture is. What are the different parts of it, why we need environmental architecture. In fact I had a presentation, which I used to give to all these places, and still there were no takers for it for a very long time." Roshni Udyavar Yehuda, Head of Department of Environmental Architecture at *Rachana Sansad* (Mumbai 13/02/2010) on promoting an environmental architecture degree.

This quote identifies a difficulty in communicating the ideas of environmental architecture. It is not just that people do not see the benefits to themselves financially and to the wider world environmentally, but that the combination of supply routes in buildings successfully creates the illusion of constant supply. Now, after the floods and droughts of recent years, the idea of installing rainwater harvesting is becoming more widely known and ideas about other environmental initiatives are being taken up with the new role of housing as service provider (see Section 5.3). The legislation for mandatory rainwater harvesting in new buildings was the simple motivation for some of the schemes in Mumbai and this legislation is thus an important part of many rainwater harvesting assemblages. City and state legislation are a discursive part of the assemblage of rainwater harvesting and influence it as they are translated into material parts (McFarlane, 2011). Even the legislation was not enough to make some developers adopt the technology and instead they hire equipment to give the appearance of a rainwater harvesting system during inspections.

6.4 Designing the system

Design decisions are unpacked in this section, providing an opportunity to compare the different systems and the reasons for their design, particularly in different scales and in retrofit versus newly constructed. This begins with the process of site surveys and considers the choice of appropriate systems for the conditions of the site and/or building(s). This process begins to relate the discursive elements of the assemblage to the material in various translations. Heterogeneous elements are drawn into the assemblage drawing the design process as the process of territorialisation also begins. This section also discusses the roles of different experts in the process and how the different elements of the rainwater harvesting assemblage are designed, chosen and brought together.

6.4.1 Surveys and permissions

In an ideal situation the initial consultation process to design a system would involve an architect or building engineer but I have observed no evidence of this involvement, which would allow for whole-system thinking and possibly more elegant solutions. The assessments are carried out at the level of the rainwater harvesting system by consultants. The geologist establishes the feasibilities of recharging the ground water due to the ground water levels and the rock type below the site.

> "So first we do the survey of the place. And we invite the survey geologist. The geologist department – the person comes inspect the place: whether water is available and at what level." Gurjeet Singh Bedi, *Osmosis* (Mumbai, 24/01/2011)

The surveys will also suggest the different types of collection (roof/garden) and the delivery throughout the building, so the design process begins with surveys by a geologist and rainwater harvesting specialist to determine the options for that particular site and/or building.

> "So then you need to have a geological survey done. To see where the points are [of extraction and of services in an existing building] and that becomes a little more expensive. But it's much tougher incorporating anything into an existing building." Shyam Balsekar, *Linear Technology* (Mumbai, 06/11/2009)

This survey process engages further with water in the wider environment, such as level of the water table, and other elements such as soil and rock type and salt in coastal locations. The survey is the beginning of a translation into material elements as the discursive concepts are linked to the material site. There are several different collection systems depending on whether the water is collected from the roof or surrounding grounds, and the BMC provide rough schematics. Permission is also needed from the water department and pest control because mosquitoes are a disruptive part of the rainwater harvesting assemblage. As Mr Singh says about the need to get consent from the pest control department of local government:

> "Definitely the mosquitoes will come. To protect from that, we require the permission from them [the pest control authority]. And they've got certain terms and conditions which are to be followed and after doing that, we put our notice board of that this water is not for drinking purpose." Gurjeet Singh Bedi, *Osmosis* (Mumbai, 24/01/2011)

This sign itself has an important place in the assemblage, responding to the legislative pressures, modifying behaviours of human actants and translating part of the assemblage into a discursive element. The reports and diagrams produced have an important, although transient, place in the rainwater harvesting assemblage. If water is stored in a tank it is particularly at risk from mosquitoes breeding in the calm waters and this can lead to health issues, such as malaria and dengue fever. In *The Secret Building*, a small apartment building with a retrofitted system (see Appendix 2), the water is stored in a tank and chemicals added to prevent mosquitoes (as will be discussed later). This again demonstrates the control exerted by human agency over nature and the difficultly with which this is undertaken (Kaika, 2005). The practices have been created and chemicals incorporated to exclude breeding mosquitoes and bacteria at point of storage in this rainwater harvesting system.

6.4.2 Rainwater harvesting configurations

There are complicated and interlinked decisions to be made when designing a rainwater harvesting system to install in a building. A huge number of factors influence the design of a rainwater harvesting system and each system must be designed for the specific site and building(s) but there are certain commonalities. The three rainwater harvesting routes were introduced in Section 3.6.3.2 through the guidance from the municipality. In this section I deepen that discussion by explaining the pathways in more detail and considering the motivation for these routes, and their implications for collective and individual water security.

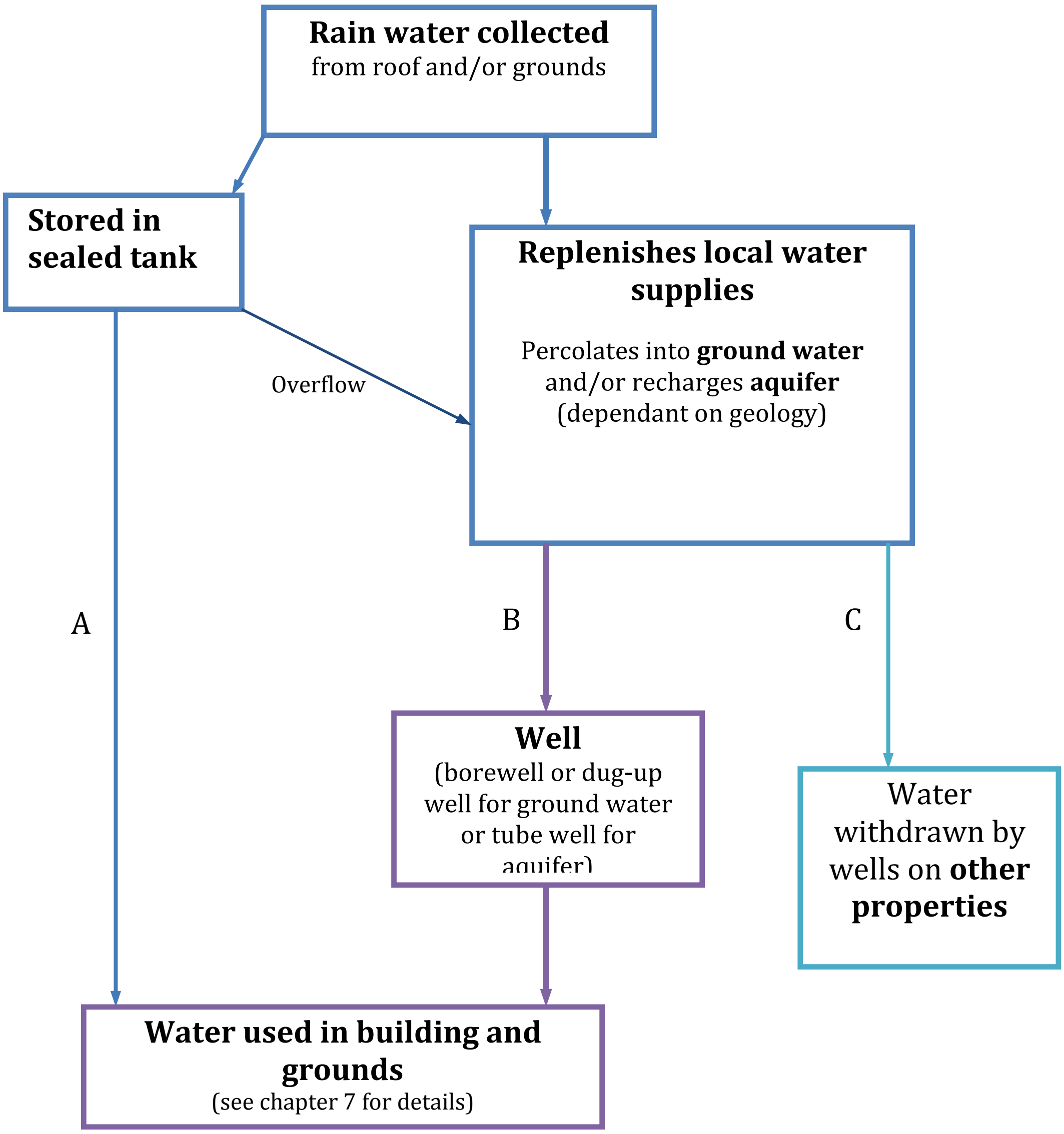

Fig 6.2 Rainwater harvesting pathways schematic diagram (Source: Author)

I have drawn fig. 6.2 to clearly show the different pathways that can be chosen for rainwater and form the basis of any system design. The three routes that harvested rainwater takes are:

A. Water is stored in a tank and the rainwater can be easily accessed and used. This pathway directly replaces water that was previously supplied by water tanker (see fig. 3.7). Water is made available instantly from the water stored in the tank, but it is quite limited, unless an extremely large tank is available. As this is a limited supply, it is not the favoured route, but is often used in conjunction with pathway B. Water is available instantly and in the long term when that the two routes are combined. They can be included separately or with route B supplies from an overflow from the tank in route A, as seen in fig. 6.1 at the *Sealine* building.

B. Water is used to recharge the ground water (or sometimes an aquifer) and water is then later withdrawn using a well to be used in the building and grounds. This is the route that I found to be favoured in retrofit because it allows for a large volume of water to be added to the water table. The amount of water that is replenished and that withdrawn might differ and there is no regulation of this. Currently the amount withdrawn seems to be less than put in, as the level in wells has risen slightly, but this may not be the case in all systems and may not continue in the future. Metering the water put in and withdrawn would be one way to monitor this. The collected rainwater is not bounded (as in A) and might flow away from the original property and be withdrawn elsewhere, as shown by route C. Route B is also popular because it reduces the risk of mosquitoes breeding in the water whereas in route A chemicals would need to be added to reduce the mosquitoes.

C. This is the route favoured by developers of new-build properties and fullfills legislative requirements. If percolation happens in gardens, then it can be used to water them as it drain away and such soakaways are popular. The rainwater in pathway C replenishes the local water table (or aquifer) as in route B, but it is not directly withdrawn for use in the building. The water may be withdrawn by wells on other properties and so might improve the water security of nearby properties.

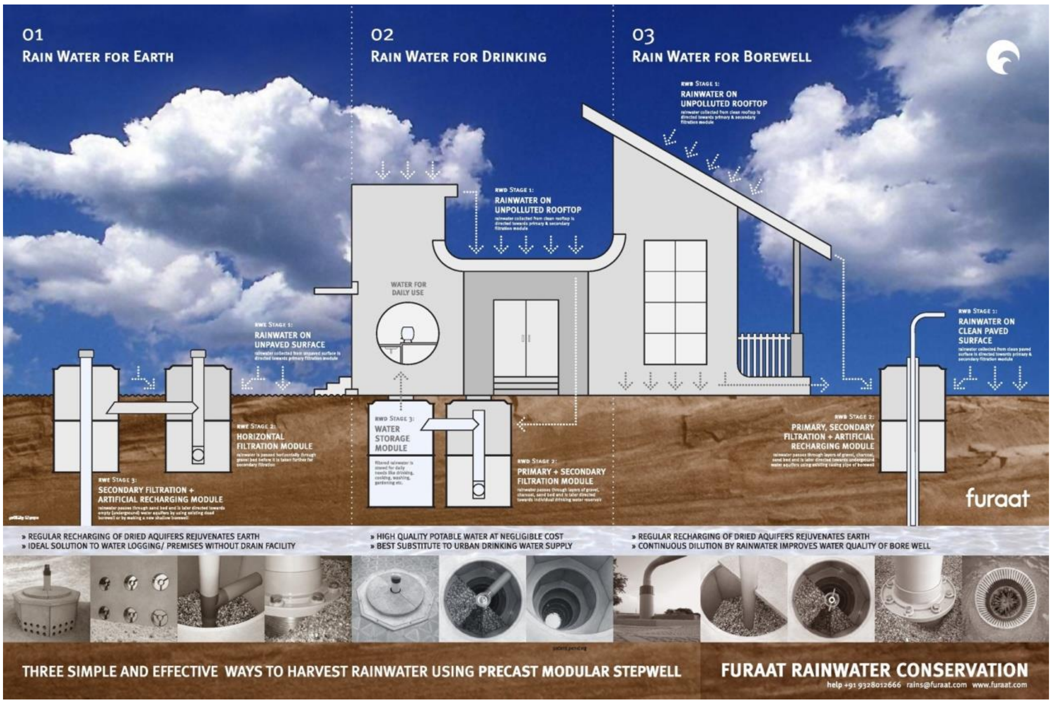

Figure 6.3: Diagram of different configurations for Furaat (Source: www.furaat.com)

Templates and suggested design layout can help in the decision process, but they can also influence that decision. Fig. 6.3 is an illustration produced by Furaat (a company supplying precast elements for rainwater harvesting installations) that shows three standard configurations in which their component are fitted and what the harvested water is subsequently used for. These system designs map onto the three pathways demonstrated in fig 6.2:

1. The first is an example of route C (in fig. 6.2) and is a simple system of recharge from the surface to the ground water, often installed in new builds.
2. The second option is a design for route A and shows the collection of rainwater from the roof and storage in a tank. The water is then filtered to make it potable, something that will be discussed further in the next chapter, but this is rarely seen due to space constraints and regulations regarding the consumption of harvested rainwater.
3. The final option presented is to collect rainwater from the roof and recharge a well for later extraction, which is the type of system most commonly retrofitted, and is a useful illustration of route B from fig. 6.2.

All three layouts make use of the Furaat step well but demonstrate how one component's position, relationships and roles can vary depending on the assemblage of which they are part, but that the prefabricated well can have a role in different assemblages (Bennett, 2005). Certain elements of the assemblage are designed as modules and fabricated away from the site: this includes element of the process such as the recharge well in some systems.

Documents such as this can be seen as 'inscriptions' (McFarlane, 2011) and are used as publicity and education that could draw new actors into the assemblage. The Municipal Corporation of Greater Mumbai has also produced diagrams of potential configurations of elements within a rainwater harvesting installation together with writing (see Appendix 6) (Municpal Corporation of Greater Mumbai (MCGM), 2008, Municpal Corporation of Greater Mumbai, 2003). Fig. 6.1 is a system drawing of the rainwater harvesting assemblage at *Sealine Apartments* created several years after installation, showing the spatial and element imaginary. These documents are as much a part of the assemblage as the consultants or the pipes. These diagrams simplify the processes, but are useful for the purposes of explanation and have a transformative impact on the assembling of systems by suggesting configurations of homogeneous elements (McFarlane 2011).

All systems need to be designed in consideration of the building that they relate to, the rainwater harvesting assemblage is thus nested within the building. Some systems are designed and constructed entirely *in situ* not using schematics or pre-cast components. Two examples are *Sealine Apartments* where trenches were dug as soakaways and *Kanti Apartments* where flowerbeds are used as water filters (fig 6.7).

6.4.3 Simple rainwater harvesting designs

The next step up is to design the collection of rainwater from the roof and/or terrace. The simplest rainwater harvesting systems observed in Mumbai use the existing slope of the road and some additional concrete to guide monsoon rains into storm drains, which then fill a tank. Fig. 6.4 shows such a simple system, one would hardly know it was there and it allows parking to still take place above. The grill in place stops leaves and large parts of debris entering with the flow of water. Another simple way the assemblage has been put together to deny leaves and litter inclusion, demonstrating how the unwanted elements influence design.

Figure 6.4: Simple storm drain collection designed to exclude leaves (Source: Author)

> "Basically you have to take water from the terraces. So there's a filter that we fit onto the drainage pipe. The storm water pipes. We filter the water and then that goes straight into your collection. So we can re-use that water, say for car washing or…. Where presently they are using the potable water". Shyam Balsekar, *Linear Technology* (Mumbai, 06/11/2009)

Thus in this possible rainwater harvesting assemblage the roof is the point of collection for the rainwater, which is then filtered to remove dust and rubbish. The water is then stored in a tank or recharged into a well for use outside, without further treatment. The capacity of the system will depend on the number of flats to be supplied and the collection area combined with the type of storage/recharge: each one affecting the assembling of rainwater harvesting.

> "So just the terrace of an apartment building that would be say 500 to 700 square metres. Means you are collecting between 1.4 to 1.5 million litres per year. So it's a lot." Shyam Balsekar, *Linear Technology* (Mumbai, 06/11/2009)

The amount of water collected means that storing it in a tank is not often an option. A tank is an enclosed storage chamber[21] that is directly filled with water (see Section 3.6.2.4), for example the tank at *Sealine Apartments* holds only 10,000 litres (see fig. 6.1). The holding of a tank of water also creates the potential for mosquitoes to breed. This system saves potable water and thus saves energy that would be used to treat water to a high standard. It is more usual in Mumbai to include the recharge of the ground water or an aquifer for later extraction by a well, rather than tank storage due to the monsoonal nature of rainfall. The recharging of ground water by the building shifts the boundaries of the assemblage because the water could be withdrawn by systems in another building. This more complex assemblage has the benefit of excluding breeding mosquitoes by not having a tank of water. The incorporation and exclusion of different natural elements in the assemblage is crucial to rainwater harvesting.

6.4.4 First flush valve

The first flush valve is a component designed installed in every rainwater harvesting assemblage. It is a valve that allows the first rains of the monsoon to flush out debris from the system to clean it and this water is discarded using the first flush valve and the clean(er) rainwater is subsequently collected. Leaves and litter are unwanted parts of the assemblage and so the rainwater harvesting system must be designed to deal with them. This valve allowed them to be washed through the system in the first rains and sent into the storm drains.

[21] These are usually underground in Mumbai to allow parking above.

Figure 6.5: First flush valve to clean the system (Source: Author)

At the very beginning of the monsoon the first flush valve is used in almost every system to allow the water to wash dirt from the terraces, grounds and pipes, and this water is directed into public drains. The valve is then turned back to collect or recharge the cleaner rainwater into the systems. Elements, such as the inclusion of this valve, highlight the tension caused by unwanted parts of the assemblage where the design of the rainwater harvesting system must be altered to exclude these parts and thus change the assemblage (de Laet and Mol, 2000). This maintains the function of the rainwater harvesting assemblage but these elements (such as leaves and litter) has still changed the assemblage. These unwanted elements demonstrate their agency by changing the assemblage from the outside.

6.4.5 Prefabricated elements

The collection system has symbiotic relationship with the design of the storage or recharge process as all work together in the same assemblage. If the assemblage is a process, then one part reacts to changes in another and this response can happen even at the design stage. The storage or recharge system is sometimes prefabricated and Furaat wells are one such example, see fig. 6.6 below. Furaat is an Indian company that supplies recharge pits and wells in the form of pre-cast concrete step wells. This modern technology draws on the traditional step wells of Rajasthan in arid Northern India (see Section 3.6.3.1), drawing vernacular rural infrastructure configurators in this response to urban water shortage.

Figure 6.6: Furaat recharge pit and well (Source: Author)

The image above is of a Furaat well installed by Mr Singh of Osmosis in the front garden of an apartment building on Carter Road, Bandra. Even though it is on the seafront the well still draws sweet water (rather than salty). Salination of the water can be an issue of a borewell is dug near the coast. This highlights the importance of carrying out surveys early in the process to inform the design and choice of location, and thus exclude unwanted elements such as salt. This control of nature is explored in the context of Athens by Maria Kaika who states that "Instead of being fearful and threatening, nature became tame and serviceable, a prerequisite for development. In turn, the city was reconceptualized as a realm outside the reach of nature's processes" (Kaika, 2005: 107). The taming and control, or domestication, of nature is in this way seen as not just central to the supply of clean water but to the development of the city itself.

6.4.6 *In situ* design

The variations and flexibility of approach makes rainwater harvesting a rich opportunity for innovation. The image below shows how flowerbeds are part of the rainwater harvesting assemblage at *Kanti Apartments*, not just as end users, but also as a filtration system for the rain and grey water. This is a novel way for soil and plants to be incorporated into the assemblage, when at other stages of the process the system is designed to exclude plant material and dirt, utilising nature rather than excluding it. Grey water is incorporated with the rainwater to create combined wastewater to be treated. Kaika (2005) describes this type of transformation as the water becoming 'bad nature' again by the metabolism processes of the home. The two waters are treated together and this also has the additional benefit that these flowerbeds do not need water at any time of year. This is a system that responds to the unique site and to the already established building. It is an attractive solution for those buildings that have the space, a rare luxury in Mumbai.

Figure 6.7: Flowerbeds are used to filter water at *Kanti Apartments* (Source: Author)

The system in fig. 6.7 is a rare example of a rainwater harvesting system that is deliberately visible. The visible and striking design of this system could be used to raise awareness of rainwater harvesting and lead to take up by other residents by raising its profile. During my site visit to the *Kanti Apartments* it was being filmed as part of a documentary about water conservation. Rainwater harvesting is usually not visible but instead hidden on rooftops and underneath car parks. This can be considered to be for two reasons, firstly to minimise the use of space for the system as space it at the premium in Mumbai and parking spaces around apartment buildings are precious. Secondly, visible infrastructure within domestic buildings is not desirable, and wells and other material components of the rainwater harvesting assemblage are often sunk under car parks to save space. Thus there is an attempt to 'black box' the system and this concealment can deny the assemblage some of its discursive possibilities (McFarlane, 2011).

6.4.7 Assembling as innovation

The process of assembling and aligning the water supply is an innovation in itself. Adaptation of the water systems within one block of flats during the retrofitting of a rainwater harvesting system demonstrates the way that these changes and transitions are constantly occurring in the city. It is the instability and changing nature of assemblages that lend them to being sites of innovation. The ways in which change occurs in an assemblage are translating, dis-assembling and re-assembling, and tinkering (discussed in Section 2.4.2). The design process is part of the translation process from discursive to material. Processes of assembling, dis-assembling and re-assembling the rainwater harvesting system during maintenance can have a transformative effect and improve the functioning of the system. However incremental changes for small improvement over time, or 'tinkering', also provide innovation (Mol, 2010).

> "Indeed, there is some evidence to suggest that this kind of piece-by-piece adaptation is a leading cause of innovation, acting as a continuous feedback loop of experimentation which, through many small increments in practical knowledge, can produce large changes." (Graham and Thrift, 2007: 5)

Graham and Thrift (2007) see the processes of maintenance as producing innovation. This is how green technologies are conceptualised as emerging and being used in homes in India, born of necessity and retrofitted as an adaptation to the situation and not publically acknowledged. These innovations are often undetected and failures in the system bring them to light.

6.5 Constructing rainwater harvesting

The methods of construction vary from site to site but all engage in the translation from discursive ideas on plans and within conversations into a material system. The differences of sequence, techniques, tools and workers between projects mean that different actants come together at various points during any assembly process. This section aims to give insights into the process of assembling rainwater harvesting and embedding it into the buildings and the city. Systems at different stages of installation are presented below for interrogation and comparison in analysis of the processes. Different stages of assembling draw different heterogeneous components into the assemblage. Processes of dis-assembling and re-assembling continue to change the components and emergent properties. This analysis captures moments of instability in the assemblage that would not be captured by looking at the original plans and/or the finished system.

This analysis concentrates on the retrofit of rainwater harvesting into small and medium sized middle class apartment blocks but also makes some comparisons with larger new-build projects. Construction processes are described using vignettes drawn from videos and field notes gathered during several site visits. These site visits were undertaken with the consultants that are overseeing (or oversaw) the rainwater harvesting installation process and are presented in a broadly chronological order, as an installation would progress. Four snap-shots of retrofit case studies will be presented before a consideration of the process at a new build construction site. The first case study is a project that is about to begin. It is being surveyed and getting permissions in place. The second project has started on site and the holes for borewell, recharge and filtration are being dug. The third project presented here is having the pipes laid that link other parts of the assemblage together. These snap shots are slices through moments of flux that help us to envisage the whole assemblage. Finally I will consider the process of assembling rainwater harvesting as part of a new build construction process to interrogate how the timing of installation of the material system alters the process as a whole. These case studies are vignettes from site visits and are snapshots of rainwater harvesting assemblages.

6.5.1: From paper plans to holes in the ground

As discussed earlier, there are many surveys and permissions that must be undertaken and obtained to inform the plan of the system. This draws policy into the assemblage through legislative mechanisms (McFarlane and Rutherford, 2008). The legislation and policies discussed in Chapter Five have agency within rainwater harvesting assemblages, and affect the design and construction of rainwater harvesting systems. Once the surveys have been undertaken and permissions granted for borewells, and the designs have been drawn, these discursive elements are then translated into the material rainwater harvesting system.

This case study is a building, *Bandra Colony*, at which this translation process is just beginning. From the geological survey it is known that solid rock lies underneath the compound and this changes the design and installation process for many material elements of the assemblage and brings a new set of tools into it, such as mechanical drills, which will soon arrive on site. The area of ground is flat and bare waiting for the system to be embedded. Instead of a site visit to see holes in the ground this was a site visit to see where potential holes in the ground would be made. The rainwater harvesting consultant (Mr Singh) and the co-operative society president of the buildings discussed the process that was about to start and indicated where parts of the system will be. This snapshot gives insight into the moment of translations, as ideas begin to crystallise into materiality.

6.5.2: Construction workers and tools: temporary elements of rainwater harvesting

The second project has begun on site and the holes for the borewell, recharge and filtration are being dug. The two men, pictured below, are daily hired labourers who are employed by the rainwater harvesting consultants/company to undertake the task, unlike the site above; the holes can be dug by hand. The soils is taken away in small amounts and put on a truck to be removed for the site. These men and their tools are a transitory part of the assemblage, without whom the aim of harvesting rainwater would not be achieved. This emphasises the importance of temporary parts of the assemblage and the fluctuating process of assemblage.

Figure 6.8: The well is dug by hand (Source: Author)

During this part of the construction process the assemblage is particularly unstable and is also at its most visible, as seen in fig. 6.8. The rainwater harvesting assemblage is disassembled and reassembled dramatically during the construction phase and the temporary or transient nature of some of the actants has been explored here. The day-labourer and his pickaxe are vital in the process of translating the ideas and plans into a material system to collect rainwater but they are only actively part of the assemblage for a limited time. As the construction progresses, it becomes more stable and hidden. This process can be seen in Deleuzian terms as the territorialising of the assemblage, it is the moment in which the assemblage claims its space (Deleuze and Guattari, 1994, De Landa, 2006).

6.5.3: Laying the pipes to control flows

The third assemblage snapshot presented here is the stage of having the pipes laid that link other parts of the rainwater harvesting together. Workers are again on site here and the site visit allows the consultant (Dr Joshi) to check on progress and inspect the installation. This system is almost entirely installed and yet has not begun to perform its role as collector and provider of water. As a system retrofitted into a building, the elements have been added to the building around existing structure and residents. This causes some disruption to the residents, who have had to move their vehicles for the laying of pipes, as well as the noise of installation from workmen and digging.

The exposed pipes give a sense of water flow, as it will be directed into and through the pipes. Visiting the site at this moment of assembling thus allows a view into the interactions of components that will be later concealed under the car park. The pipes are a material indication of how rainwater harvesting interrupts the urban metabolism of water and controls nature (Swyngedouw, 2006, Kaika, 2005). The tamed water will flow from the roof terrace down pipes in a courtyard then under the ground to the recharge pits. The water in percolated into the ground for later extraction.

6.5.4 New build

In a new build construction, the installation of rainwater harvesting is comparatively straightforward and should be one of the first processes to be undertaken on the building site so that the water can be used during the construction process:

> "Water is 5%-8% of the construction costs so rainwater harvesting should be the first thing that is done before construction starts." Sanjay, Developer (Mumbai, 12/11/2009)

So the rainwater is not just used within the everyday practices of dwelling (as will be discussed in the next chapter) but also as part of the construction process of a new build apartment block. This is a reversal of order in assembling the system as the rainwater harvesting is in place before the building. This installation at the beginning of construction in a controlled manner reduced the flexibility of the system and the chances for innovation through tinkering or dis- and re-assembling the system that are possible in retrofitted systems.

The actors involved are different for a new build property as developers and builders are in charge and have the power, whereas the residents do not yet exist and so do not influence the design. I visited a few new build properties at different stages of construction

It is currently the tallest residential building in Mumbai (soon to be over taken). It is nearly 165m tall and has 5 towers of 47 storeys joined together to make one structure. The parking is located on the ground floor and the main entrance on the 1st floor to 'touch the earth lightly' as heavy groundwork is not then needed. However it does rather encourage the use of cars and make approach on foot less pleasant. The footprint of the residential tower also only uses 5% of the site. The rest of the site is green area, although this does largely appear to be yellowing grass and hedges and there is a swimming pool and clubhouse for sporting activities (although no-one was using it, I assume some residents do). There is an extensive rainwater harvesting system in place. This collects storm water from the terrace (roof) and also from the green areas of the grounds and replenishes the ground water for bore wells. However the water does not seem to be used in the building itself.

Box 6.1: Excerpt from building visit to Large Developer's building (Mumbai, 12/11/2009)

The except from my research diary in Box 6.1 explains the increase in scale here as the new apartment buildings are high-rise and tower over the older buildings visited. The role of rainwater harvesting in the new build is also different from the retrofit. The system is installed to satisfy the authorities and to replenish the groundwater. This percolation into the grounds allows for gardens to be planted, but the water is not used for any other domestic practices.

6.6 Maintaining the assemblage: disassembly, reassembly and exclusion

> "Repair and maintenance are not incidental activities. In many ways, they are the engine room of modern economies and societies." (Graham and Thrift, 2007: 19)

Maintenance creates instability in the assemblage. Graham and Thrift (2007) and de Laet and Mol (2000) acknowledge the transformative potential of maintenance through incremental change or 'tinkering'. This dis-assembly and re-assembly can lead to innovation as systems are incrementally adapted and improved. Leaves, litter, dirt, bacteria and mosquitoes are the unwanted and excluded elements of assemblage and so the focus of maintenance. This tension between the nature that we tame and commodify and that which we purposefully exclude from the assemblage shows that rainwater harvesting assemblage is not just to collect rainwater but to provide safe clean water to be used in domestic practices (Kaika, 2005). The assemblage is designed and orientated to exclude elements (de Laet and Mol, 2000). This section explores the different ways in which maintenance is undertaken as part of several assemblages. Maintenance is a key part of the assemblage, as it keeps the process going and draws further actants into the rainwater harvesting assemblage. This is particularly significant in Mumbai where maintenance often doesn't happen, but in this assemblage can be vital for the process to happen.

The disassembling and reassembling of the assemblage can have a transformative effect and is a large part of the maintenance of rainwater harvesting. This maintenance is an important part of the process of assembly (McFarlane, 2011). De Laet and Mol (2000) also see maintenance as creative, and repair rather than replace is an important part of the evolution of the assemblage. Daily and annual maintenance is vital to keeping the rainwater harvesting process flowing. This kind of ongoing maintenance and repair can be seen as a kind of resilience that does not just return the system back to its original state after a breakdown but allow it to change and to bounce *forward* (Shaw and Theobald, 2011).

Harvested rainwater is used mainly for flushing toilets, cleaning cars and watering gardens and use of water in everyday life will be unpacked in the following Chapter Seven. The focus here is on the maintenance of the processes of rainwater harvesting assemblage and how the physical process of harvesting rainwater takes place. Maintenance is daily, annual or sometimes on an *ad hoc* basis, or indeed a combination of these, depending on the specific assemblage involved at that moment in time and space. This gradual upkeep is central to the survival of the assemblage with maintainers having a pivotal role in the process and can alter the assemblage and add new elements (Graham and Thrift, 2007, Mol, 2010). Within this section examples are used to unpick the place of maintenance in the assemblage process. One case study requiring intensive annual maintenance is presented followed by one requiring daily maintenance; finally these are compared with the industrial scale treatment plant at *Hiranandani Gardens*. The systems require different types and levels of maintenance, but one commonality is that the maintenance is largely undertaken to *exclude* certain unwanted parts from the assemblage. So it is not only the design of the assemblage that is used to exclude but also the ongoing process of maintenance.

6.6.1: Annual maintenance

Annual maintenance is the starting point for the empirical exploration. The first case study is a retrofit system that requires annual maintenance to remove unwanted materials and check the system. This annual work is still carried out by the installation consultants. The below image shows one of the consultant's employees clearing leaves from the rainwater harvesting collection system. This task is undertaken during the dry season (winter), after the leaves have fallen but before the rains begin again.

Figure 6.9: Leaves from system by Osmosis employee (Source: Author)

Before the monsoon the filters of all rainwater harvesting systems must be cleaned, as shown in fig. 6.9. The leaves, litter and dirt are removed from the assemblage before the collection process starts and these unwanted materials exert their agency and disrupt the process by blocking pipes and filters. This annual maintenance also involves the removal and cleaning or replacing of the gravel and sand in the traps and filters. This system has the Furraat wells and recharge pits that were detailed earlier and requires the cleaning of gravel as is shown in fig 6.10.

Figure 6.10: The gravel filters must be cleaned annually (Source: Author)

The above image shows a rainwater harvesting system being physically dis-assembled for cleaning and maintenance by an *Osmosis* employee. This annual maintenance is carried out either by employees of the consultant who designed the system as in the case of *Osmosis* or by the *watchman* in other buildings. This depends on the consultant used and the length of time since installation of the retrofit. In new builds this kind of annual maintenance is provided by the building management after the responsibilities of the installers and construction teams has ended.

6.6.2: Daily maintenance

Some systems are designed to need daily upkeep. The second case study is a system that needs daily maintenance and is used to show the variety of maintenance that can be needed and to draw out the theme of exclusion from the assemblage further. The system shown here in fig. 6.11 is in *Secret Building* and stores the water in a tank after it has been filtered through flowerbeds (used as reed beds). Chemicals are added to the tank on a daily basis to kill bacteria and mosquito eggs and larvae, controlling and removing these unwanted components (de Laet and Mol, 2000).

Figure 6.11: Chemicals are added to this system everyday (Source: Author)

The figure above shows the access hatch in the grounds of the building. This permits the *watchman* to access the water in the tank to add the chemicals that are kept in the urn just seen at the top of the photograph. This system is quite a visible one (although photographs were restricted) and so it is interesting to note that the same rainwater harvesting consultant was used for this system as the highly visible one at *Kanti Apartments* as discussed earlier. This variety shows how the specifics of site and client change the system and form different assemblages. "In most of the mega-cities of the global South, for example, the fact that urban life is the result of continuous efforts of infrastructural improvisation and repair is too overwhelming and visible to be ignored" (Graham and Thrift, 2007: 11). These processes of tinkering and adding to the assemblage are constantly taking place, especially where maintenance is daily. The watchman at the property undertakes adding the chemicals and these watchmen can thus be an important part of the assemblage. In most middle class buildings the watchman is central to keeping the different water systems flowing.

6.6.3 *Ad Hoc* Maintenance

Other maintenance may sometimes also be necessary to keep systems flowing, such as at *Sealine Apartments* where the trenches (that provide soakaway) were being cleaned and rubbish removed from the system. In new builds the developer may sometimes still be willing to help:

> "It's not written but is just is you know if somebody calls me. Like is this building there was a problem with water seepage, water seepage happening because of the rains. That's something that's unavoidable. […] You know we don't want to leave people high and dry, if there's an issues we'll do it. But it's not a part of the agreement or anything like that. But this building is about 5 years old. And people still call us if there's an issue and we go sort it out." Gaurav Monga, *EcoHomes* (Mumbai, 16/12/2009)

So maintenance and repair may not be formally organised. The maintenance of systems is negotiated by the residents or managers of the building. The removal of rubbish and the washing of filtration screens may be necessary and repair is also required at times of breakdown or blockage.

6.6.4 Keeping the water flowing in a township

The *Hiranandani* township is of such a size that the waste water and sewage must be managed and at least pre-treated on site before it is released into the central sewage system. It is the largest project that I visited and has several entangled water provision assemblages across the site. The township treats the greywater and rainwater entirely and recycles it back into the township, closing the metabolism loop. New apartment blocks in the township have their own rainwater harvesting systems, but those built early in the development are merely part of the centralised system. Some of these older buildings have now had rainwater harvesting retrofitted.

The large treatment plant at *Hiranandani Gardens* also needs daily work and has a team of engineers who build and oversee the maintenance of systems in the township. The township is a large area in Northern Mumbai for upper-middle class residents but draws on rural imagery and some ecological ideas (Gandy, 2009). One of the township engineers showed me around the various systems that are in place for collecting and treating rainwater, storm water and grey water across the township. The treatment plant is large but tucked away at the back of a park, so that you would not even know that it was there.

Figure 6.12: Chemicals are added and checks undertaken everyday (Source: Author)

Standing over the rushing waters of the treatment plant, flowing so fast they appear white. *Hirandandani Gardens* shows the scale of the operation of collecting and processing the rainwater and grey water from the township. This treatment plant is concealed within recreational public gardens, so that from the within the gardens, visitors rarely realise that they are actually strolling through a sewage treatment works. This again shows the innovative use of gardens within the rainwater assemblage, but this time at a larger scale. The water cascades through several filters and has chemicals added to it (sodium hypochlorite, calcium hydroxide and alum powder). The quality of the water is then checked every day before being fed back into the water supply. The management perform their own quality checks (as shown in fig. 6.12 above), as do the MCGM. Some assemblages are extremely large and complicated, but this is often dependant on scale. This is just one small part of the extensive system of water infrastructure in *Hiranandani Gardens*, which sits on the edge of Powai Lake. In most new builds it is likely that a maintenance company will be in charge for the first few years at least.

Maintaining rainwater harvesting systems changes the assemblage in the ways discussed in this section. Maintenance is also crucial to the debate of housing and infrastructure in Mumbai, often through its absence that can cause buildings to collapse (Baliga, 2010). The ongoing upkeep of the city changes the city's infrastructure, through the installation of rainwater harvesting systems into individual buildings, and their subsequent maintenance, in order provide water and reduce flooding. These are not large, deliberate interventions but the small-scale responses that change the city. The rainwater harvesting may compete with other water provision infrastructures, this may result in a replacement or in these infrastructures working side-by-side in a larger water-provision assemblage, that can be seen as a part within the larger water infrastructure of the city. This use of housing as a provider of water also signifies the new role of housing discussed in Chapter 5 that sees housing as being a tool for the governance and of water supply. Rainwater harvesting can thus reduce pressure on centralised infrastructure.

6.7 Directional change and apertures in socio-technical transition

Assemblage engages with change but the changes through disassembling and reassembling and even translation cannot fully explain technology uptake or changes in governance regimes. Thus I use socio-technical transitions to conceptualise the changes in the system and particularly how rainwater harvesting is playing a pivotal role in this transition. In this section I introduce socio-technical transitions as a way of conceptualising directional change, in particular the uptake and mainstreaming of a particular technology, and how this has been used to describe the shift towards more sustainable futures in cities. I then consider how these changes are taking place through processes of alignment and the creation of pathways.

Rainwater harvesting has found its protective space within which it can be nurtured ('niche') amongst existing regimes (Guy, 2006). Lovell (2007) develops the niche concept further using the example of the UK Government's strategy for low-energy housing as 'strategic niche management': the creation of niches for technological innovation and then the dissemination of knowledge. Much of the time the government finds examples created by enthusiastic individuals or groups and then associates itself with them, as a way of encouraging innovation. The niche-approach in socio-technical innovation is relevant to this research as it is these niches that will be studied: domestic infrastructure interventions. However, although niches are an important part of the socio-technical transition process, they alone are not enough (Seyfang, 2008).

Alignment is important for the integration and dissemination of technologies**.** All new technologies are developed against a background of existing socio-technical regimes, and new pathways for the progression of socio-technical regimes must be constructed (Rip, 1995). "However, not everyone will agree to change, dissent and resistance play an important role in precipitating and modifying processes of change" (Smith et al., 2005: 1508)**.** There must be mechanisms for the diffusion of these socio-technical ideas into the mainstream to create the transition.

Rainwater harvesting may be one technology with a unique role in Mumbai, and in the socio-technical transitions: that of disruptor and/or catalyst. The installation of rainwater harvesting (which could be seen as a 'low hanging fruit') acts as a catalyst for the installation of other technologies. Thus the future of urban interventions to address water shortage and environmental change could lie in domestic retrofits but these changes are hidden and cannot be used for corporate 'greening' (like a large wind turbine can) and they are also capital intensive and rely on the interest of the homeowner. One of the major problems with researching and promoting environmental retrofits is that they are usually hidden within the urban fabric: rainwater harvesting is deliberately concealed under car parks, so that the much of the assemblage is not visibly self-promoting.

Rainwater harvesting is creating socio-technical transition pathways for domestic environmental infrastructure and technology as well as governance approaches. In this section that hypothesis is interrogated using empirical data from several case studies. One extraordinary case study that demonstrates the effect in an exaggerated manner is the *Sealine Apartments*: Several environmental technology assemblages have been installed in the building and the society secretary is now involved in dissemination of environmental ideas and consulting on rainwater harvesting installations. The process of governance evolution is also picked up again here, as a continuation of discussions from Chapter Five, to consider whether the incorporation of one environmental idea into legislation can ease the process for including other technologies.

6.7.1 Apertures in retrofits

Once rainwater harvesting has been retrofitted in a building, I observed that other technologies are sometimes subsequently installed. The installation of rainwater harvesting (which could be seen as a 'low hanging fruit') acts as a catalyst for the installation of other technologies. The rainwater harvesting assemblage disrupts the building and destabilises its relationship with infrastructure. If the rainwater harvesting is successful in providing additional water to the building then it can lead to other retrofits. This is particularly true if the rainwater harvesting saves the residents money. In this way rainwater harvesting can be seen as creating *apertures* through which other technologies can pass. The apertures are in the material fabric of the building – such as pipes – and also in the residents' ideas about infrastructure provision, making them more receptive to other technologies. Thus the apertures act as portals in the transition pathways of environmental technologies.

Processes of innovation are not linear and there is the potential within the Indian context for sustainable infrastructure technologies to 'leapfrog' the fragmentary infrastructure that is currently in place, much in the same way that mobile phones have become so popular when many homes do not have a landline (Goldemberg, 1998). Maintenance may play a part here if it is preferable to install a new system rather than maintain or upgrade an old one. Decentralised back-up water supplies, such as borewells, are already common practice. Thus re-appropriating this into the rainwater harvesting assemblage might not be such a leap in real terms.

The *Sealine Apartments* in Bandra is a small apartment building in the western suburbs run as a cooperative society, as is common in India. Previously the society had to call in water tankers to top-up the water supply, and this is an expensive way to source water. Thus rainwater harvesting was an attractive option, which has given the residents consistent supply and reduced costs. They have an extensive rainwater harvesting system to collect water from both the terrace and the compound; using trenches to slowly recharge the rain into the ground water to so that it can be withdrawn by a bore-well later (see fig.6.1). In times of drought this society gives out water to the neighbours living in other buildings. They have even invested in a UV water filter to supply potable water from the harvested rain in cases of severe water shortage. The rainwater harvesting system has also reduced the impact of flooding during monsoon by absorbing some of the storm water. In the *Sealine* it has started a passion for the environment and particularly the dissemination of knowledge about these environmental technologies.

> "To start with this building. We went for rainwater harvesting. And from that day we had no problem of water in this building. Then I started solar energy in the building, this is solar working now [points at lights] all our communal area lighting is solar now. My computer runs on solar. So we have no problem on power. We also started vermiculture within the society." Navin Chandra, Co-operative secretary at *Sealine Apartments* (Mumbai, 09/01/2010)

Following on from the success of the rainwater harvesting scheme the society has installed solar water heating onto the terrace, which provides hot water to all the apartments. This was subsequently followed by photovoltaic cells (solar panels), which power the communal lighting and composting biodegradable waste.

Figure 6.13: Solar water heating was installed after rainwater harvesting in Sealine (Source: Author)

The secretary has now dedicated his time to promoting environmental ideas in Mumbai and has set up a local radio station to help achieve that aim. Although the systems in this *Sealine* retrofit project are not the most elegant solutions, they work effectively and have been purposefully opened up discursively to disseminate knowledge. This is one rare moment where the rainwater harvesting assemblage has been (re)translated into documents and conversations to promote the technology, and have in fact led to the society secretary becoming an ambassador for these domestic retrofits. The co-operative secretary also helps other buildings install rainwater harvesting and renewable energy technologies showing his dedication to environmental technology promotion.

> "Personally I think going round and telling people, I mean standing at the side to tell them about [rainwater] harvesting and this and that, said 'it's not enough'. So we decided to have 3 projects." Navin Chandra, *Sealine Apartments* and *Jago Mumbai* (Mumbai, 09/01/2010)

The first of the three projects is a garden, formally maintained by the municipal corporation, which Jago Mumbai are turning into and eco-garden.

> "BMC garden being taken over for eco-garden. This will have rainwater harvesting and solar and composting and medicinal plants, then a community centre with models to explain concepts. In 2 months' time we will start a radio station, after 2 years of trying to get the license. The radio station aims to reach 2 million people and the people are invited to come and give [information and programmes]." Navin Chandra, *Sealine Apartments* and *Jago Mumbai* (Mumbai, 09/01/2010)

The lights will be powered by solar energy and the plants will be watered with greywater from nearby buildings filtered through a reed bed because the garden is on a bed of solid rock that does not allow for rainwater harvesting. The garden will also teach visitors about the environment and what can be done in Mumbai. The second project is the *Jago Mumbai* community radio station that broadcasts about social, civic and environmental ideas for the development of Mumbai. The third will be a community centre for educational and civic purposes.

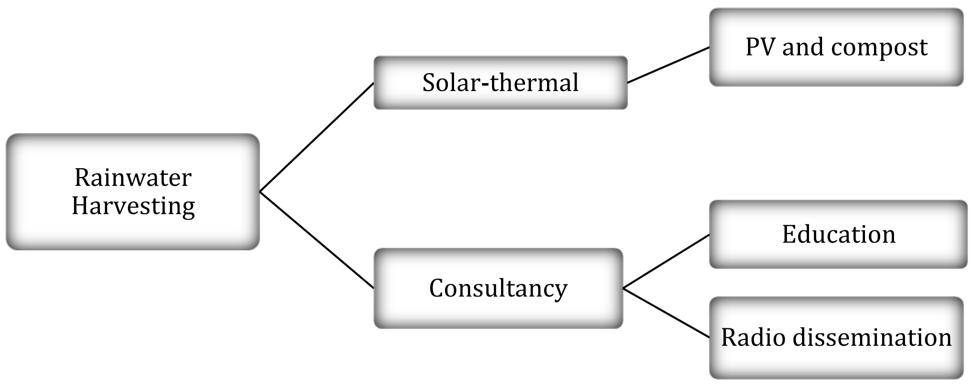

Figure 6.14: Progression of interventions in and by Sealine Building and its residents' association.

The progression along the upper trajectory in fig. 6.14 is observed in other buildings. That pathway represents how rainwater harvesting is then followed in a building by other technologies, often solar-thermal water heating.

The *Carter Road Building* is another example that demonstrates rainwater harvesting creating this aperture. Rainwater harvesting has worked successfully and residents in the *Carter Road* building are now considering the benefits of wind energy (as they face the sea) and solar energy after the success of their rainwater harvesting system. As Nadia explains the residents are waiting until they have the capital to install more technologies,

> "…in fact, next time we have a budget like this we will do the solar, and windmills." Nadia, Carter Road Building (Mumbai, 24/01/2011)

Rainwater harvesting may be creating transition pathways for the uptake of other environmental technologies by residents or builders and to be folded into policy at the city level. This would be a big step forward for the environmental agenda in Mumbai and could be transferable across India. The potential that rainwater harvesting has to create a disruption and bring attention to environmental ideas is considerable, but this is tempered by the hidden nature of rainwater harvesting once it territorialised, meaning that retrofits often lead to more, subsequent retrofits in the same buildings, but not beyond.

6.7.2 New build apertures

EcoHomes developers show that pathways are developing within businesses too. Their early projects included rainwater harvesting and fly-ash blocks:

> "So one of them was this project called 'EcoDale', which is a very small building built on a plot of about 500 sq metres. It has about 14 apartments. So we thought that was the right project to experiment with because it was just small, construction cost wasn't controlled. It was easy to build. And we employed… we did solar water heating, for the first time and we used solar. Fly-ash blocks and the architecture was done in a way that the building faces north-south and so there's no direct sunlight, you know, coming in and out, and also the flats were completely cross-ventilated – 3 side open, you know?" Gaurav Monga, *EcoHomes* (Mumbai, 16/12/2009)

Since the introduction of legislation on rainwater harvesting, and increased interest in environmental ideas, the company is now designing developments with more environmental technologies. These technologies are entering in through the aperture formed by rainwater harvesting in the company's ethos. The market is also changing to accept these technologies in buildings, aided by the new positioning of housing as site of service supply and governance. Instead of incremental improvements to infrastructure, new technology could replace the old in a rapid transformation or 'leapfrogging' (Goldemberg, 1998). This could be linked to maintenance problems in Mumbai, a city where centralised infrastructure is insufficient for current demands making the uptake of 'new' decentralised technology viable.

7 Greens is a new company specialising in renewable energy installations. Akshay and Aditya of *7 Greens* (Mumbai 02/12/2010) explained that they have not moved for rainwater harvesting first because, now it is mandatory, everyone is doing it and the market is flooded, thus they are concentrating on solar. This is an interesting example, showing that the rainwater harvesting initiative has had an effect on the market. The progression in the new build projects is closely linked to legislation changes. If rainwater harvesting is followed into legislation by other mandatory environmental technologies, then a transition towards more sustainable housing in Mumbai could be undertaken. As discussed in Section 5.4.3, the perceived success of rainwater harvesting legislation for governing the environment through housing can be capitalised on by introducing other technologies in similar ways.

6.7.3 Apertures in other contexts

Rainwater harvesting is a driver of change in service provision and in thinking about housing in Mumbai. However, in other contexts a different technology might perform the same role in creating apertures to catalyse transitions: any technology that alters ideas about building construction or service provision in specific circumstances. For example, in the United Kingdom, it could be insulation that changes the way we construct houses and leads to other environmental concepts being included. In Australia it could perhaps be photovoltaic panels. Further research into socio-technical transitions in other contexts would be needed to explore this concept that could have implication for policy and governance.

6.8 Conclusions

Taking an assemblage approach to understanding the creation and installation of rainwater harvesting systems has enabled an analysis of how the heterogeneous components come together and their emergent properties. Rainwater harvesting has thus been presented as an assemblage to explore the processes by which it is conceived of, represented and constructed. The taking of snapshots during processes of change in the assemblage has allowed analysis of moments and configurations that later change or are concealed. The assemblage then continues to be in constant flux and changing actants, particularly through the disassembly and re-assembly during maintenance. Even if the material parts are designed and built the same way, the building and residents which these parts interact with and the way in which the elements are put together, maintained and used makes each a novel and changing assemblage.

Rainwater harvesting is a process, by this I do not mean that it is the process of collecting water, but rather that the assemblage itself is in a constant state of becoming and this instability is particularly visible during the installation. The rainwater harvesting process draws together the mechanical material aspects of the system – pipes, wells, filters, spanners – with nature that is tamed or excluded – water, bacteria, leaves, mosquitoes – and with the people and practices forming the home into an assemblage. A rainwater harvesting assemblage changes dramatically every monsoon when the rains add water to the assemblage every day and some of the other elements work together to capture this water and store it. Between monsoons the maintenance has a role of disassembly and reassembly, which adds workers to the assemblage as they remove other elements. Thus the processes of maintenance can also be transformative.

The assemblages presented in this chapter have mainly been in relation to existing buildings. This makes the process more complicated because the assemblage must create a space, both discursively to become an accepted idea and physically as it become territorialised within the building and its grounds. In a new build, the rainwater harvesting is within the designs of the building from the start due to legislation. This creates a different kind of assemblage that may have a more stable position in the building. In fact rainwater harvesting may be installed before the building is even constructed so that rainwater can be used during construction. Within retrofits, installation of new infrastructure is complicated by the reconfiguration of apartments that can happen over time and by having to get everyone in the building to agree on the action and people may not want the disruption.

In this chapter I have made a contribution to concepts of socio-technical transition by suggesting the mechanism of the aperture. Rainwater harvesting can be conceptualised as creating spaces in buildings, which I have termed *apertures*, through which other technologies can pass. In this way rainwater harvesting is acting as a catalyst for the uptake of technologies into buildings through the creation of material and conceptual spaces. This has the potential to inform the way technologies are governed through an understanding of the interactions between the socio-technical transition pathways of different technologies.

Chapter Seven

Practicing rainwater harvesting

Figure 7.1: Maid's sandals outside apartment door, Bandra West, Mumbai (Source: Author)

7.1 Introduction

When visiting another country, it is often said that being invited into someone's home is the best way to experience the culture. Technologies and practices co-evolve through culture and traditions, habits and normalised practices, and the material technologies available (Shove, 2003a, Allon and Sofoulis, 2006). Thus it seems that the home is a central site for understanding another culture through everyday practices. This chapter aims to unpack how rainwater harvesting is experienced and performed in domestic buildings. Despite distributed agency, people still affect the shape of rainwater harvesting assemblages and also have their practices altered by rainwater harvesting. As water flows through buildings, it is changed by metabolic processes within everyday practices and is tamed and used, to flow out of the building as waste (see Section 2.3). It is not only the practices that use rainwater directly in the middle class home that are considered in this chapter but also the inter-related water practices that do not. Harvested rainwater is used for specific practices and this means that more water is available for other practices.

Empirical data on harvested rainwater practices in middle class apartment buildings are used to unpack the complexities of this system, its boundaries and the relationships between the social and the material. This analysis allows a flowing interrogation and considers nature of assemblage boundaries when they are crossed by practices. This structure draws particularly on Shove's (2003a) discussion of comfort, cleanliness and convenience, whereas other descriptions and interrogations of the home move from room to room or concentrate on the history of one room (see Busch, 1999, Kaika, 2005, Bryson, 2010). Everyday water practices using harvested rainwater are divided spatially into four categories for discussion: firstly, the narrative begins inside the apartment to analyse the indoor cleanliness practices mediated between the residents and female servants; secondly, the outdoor practices underneath and around the building, primarily carried out by male servants and arranged for the whole building by the cooperative; thirdly the practices that reconfigure the apartment beyond its walls by stretching the socio-technical system through outsourcing practices are interrogated in a discussion of boundaries. Fourthly the personal bodily practices of bathing and consumption are presented, showing how water practices are segmented by gender, space and class. This teases out the contested nature of drinking and bathing in rainwater and the justice implications of who has access to which sources of water. The chapter then concludes with a discussion of the influence of everyday practices on environmental technology pathways.

7.2 Housing and rainwater harvesting

"Can environmental practices be 'hardwired' into the home?" asks Shove (2003a: 15). This is a fundamental question for responses to water shortage and for socio-technical debates more generally. The installation of rainwater harvesting infrastructure could be seen as creating environmental practices by substituting a more sustainable water resource than the mains supply. However the concept that technology alone can shape everyday practices is critiqued by the socio-technical literature (Allon and Sofoulis, 2006, Guy, 2006, Seyfang, 2008, Shove, 2003a). Technologies and everyday practices are co-produced by the interactions of individual agency and infrastructure provisions. These practices are embedded within the culture of living in the middle class home, which includes the employment of servants. In this section I introduce concepts of everyday domestic practices and how these relate to rainwater harvesting assemblages.

7.2.1 Everyday domestic practices

The spatial scale and actors involved make everyday practices a useful socio-technical approach for understanding the ways in which harvested rainwater is used in the Indian middle class home. Assemblages of rainwater harvesting include people and their practices. Through investigating the middle class culture of living, I am reasserting the social aspects and human agency within the assemblage and looking at how the ways of performing practices affects the assemblage and changes relationships with water

(Simone, 2004). "The essence of sustainability lies in the recognition of agency in social choices about technological futures" (Smith et al., 2005). The power distribution and relationships in buildings can influence the decision process and the governance of infrastructure (see Section 5.6). The empirical data in this chapter looks at the social interaction and the agency of individuals to enact change through their decisions, highlighting some of the complications in the process of 'greening' everyday practices. Shove's (2003a) investigation of everyday practices of comfort, cleanliness and convenience is central to the approach in this chapter. Changes are mediated between the social, the cultural and the technical to create new normalised practices, changing the ways in which people live and consume (Shove, 2003a). Understanding this process is important for addressing water shortage and environmental change at the domestic scale, and the specificities of the Mumbai context.

Exploring housing through everyday practices gives insight into the interconnected nature of social and material cultures and the ways that environmental concerns are played out within the domestic sphere (Allon and Sofoulis, 2006). Everyday practices are part of socio-technical systems shaped by societal pressures, cultural norms and the technology available (Allon and Sofoulis, 2006, Hargreaves, 2011, Halkier et al., 2011). Mrs Mankar, a retired female interviewee living alone in an apartment block in Bandra, commented at length on the changing nature of living arrangements in India and the effect these are having on consumption (Mumbai, 17/12/2010). She explained how the shift from traditional extended families to nuclear units means that more space and appliances are needed for the same number of people, thus increasing consumption. Qayum and Ray (2011) also highlight this shift from middle class households of extended families and live-in servants to 'modern' households of nuclear families and servants who live elsewhere. Sara Dickey (2000) explains that the middle class employment of domestic servants brings people from different social backgrounds into the home, who would not otherwise interact. Bringing in of non-family members into the home disrupts the binary of inside/outside and creates a permeable boundary to the domestic sphere (ibid), as further discussed in Section 7.6. Thus the change in living arrangements, and particularly *who* is included in the assemblage, changes the consumption patterns of the middle class home.

7.2.2 Assembling housing through practices

Architectural technologies have generally been overlooked as an aspect of science and technology research but a socio-technical view of housing develops my understanding of what creates a home.

> "The acts of `housing' and `dwelling' are a coproduction between those who are housed and the variant technologies that do the work of housing: ornaments and decorations, yes, architecture and bricks and mortar, sanitation and communication technologies, too, but also housing policies and practices, mortgage lending and insurance, credit scores, and all the other lively `things' of finance" (Jacobs and Smith, 2008:517)

Housing is a node of water, energy, sanitation and telecommunications, whilst also being an infrastructure and, as explored in Chapter Five, service provider. Thus homes can be viewed as a series of human and non-human interactions where residents, and those employed by them, must work together with infrastructure and other machines in a reciprocal way to undertake practices. This means that the practices associated with the home are multiple, forming each apartment as a complex and unique assemblage created through the everyday practices and the actants involved. The use of everyday practices to view this system reinstates the importance of the social and cultural elements.

> "Rather than analyse the process of technical change internally, in terms of developments within the technology itself, or by reference to the ideas of famous scientists, inventors, and entrepreneurs, such research is interested in discovering to what extent, and how, does the kind of society we live in affect the kind of technology we produce?" (Guy, 2006: 650)

The kind of technology used and produced in a society is linked to the everyday practices of the home. Technologies and practices co-evolve through the culture and traditions, the habits and normalised practices, and the material technologies available (Shove, 2003a, Allon and Sofoulis, 2006). If one of those aspects is different or changes through disassembly and re-assembly, then the assemblage is configured differently and can have altered emergent properties (see Section 2.4.2). In middle class Indian housing, the employment of domestic servants makes this a particularly complex system as the resident is often distanced from practices and interactions within their own home, which could have implications for domestic technology uptake, as will be explored through empirical evidence in this chapter.

As water flows through the building and is used in the domestic everyday practices, it is changed through processes of metabolisms. The rainwater has been tamed and domesticated through collection, storage and treatment. This domestication of water blurs the boundary between home and nature, inside and outside, public and private (Kaika, 2006). The boundaries of the home are also altered by the everyday practices (as discussed in Section 7.6). Kaika's (2005) history of urban cleanliness via flows of water through the home, and the development of bathrooms and the practices therein, is also central my analysis of the assemblage boundaries. The use of servants and outsourcing practices are explored in this chapter as additional ways in which the boundaries are permeated and stretched.

7.3 Placing the research in middle class housing

The everyday practices, in which harvested rainwater is central, are examined using empirical data drawn from site visits including ethnographic observations and interviews with cooperative (in both senses) housing secretaries and presidents, other residents and servants at twenty-two residential properties in Northern Mumbai. The apartments and buildings used in this study range from the modest apartments in five storey buildings to large apartments in high-rise developments and townships (see Appendix 3). This range is demonstrative of the different buildings that the middle classes reside in, but the general commonality of apartment living has been used to define the middle classes within this research. The majority of middle class buildings are run as co-operatives with elected presidents and secretaries (as discussed in Chapters Three and Five). This has implications for the individual home in terms of governance, resource provision and boundaries. Some decisions can be made by the representatives alone, or with a majority support, whilst others need all parties to be in agreement particularly when funds must be collected to provide the capital to install new infrastructure. Co-operative societies are also involved in employing servants to carry out tasks relating to the whole building, such as security and waste management. It is these co-operative buildings and the apartments inside them that are the site and scale for this investigation into everyday water practices.

This section introduces middle class housing as a site of investigation, through an auto-ethnographic study of three buildings where I lived. There have been many attempts to define the Indian middle classes as discussed in Section 3.4 (see also Fernandes, 2011, Mawdsley, 2004). In this research I use the culture of living and place of residence as the parameters to identify the middle classes. Below I draw on my own experience of dwelling in various middle class apartment buildings in North and West Mumbai during two fieldwork visits between November 2009 and February 2011. Living within middle class apartments as a 'paying guest' gives me an insight into the everyday practices in the home and are presented below to provide contextual background to the other empirical data in this chapter. Three different middle class apartment buildings in North Mumbai are described below (using material drawn from my auto-ethnographic notes and research diary) to highlight the breadth of the culture of living in which this research sits but also to draw commonalities between them. The three buildings differ in age, size, demographic and water supply.

7.3.1 Residence one: Bandra (West)

The first of these three apartment blocks is a small building which originally only had three floors but has been extended vertically to six floors to keep up with demand for apartments in this popular residential and expensive area (Sharma, 2007). The co-operatives of several surrounding buildings have decided to cash in further on the demand for apartments by having theirs demolished and a tall tower constructed in its place, as land is in short supply and costly (Nijman, 2007). The building is situated on a tight plot with limited parking in front and underneath the building with a few plant pots and there is a small hut to the front, which houses a convenience store. The apartments vary from small two bedroom dwellings to larger apartments on the upper floors. The building has a mix of occupants including residents from several different religions and from different parts of India. There is also a mixture of tenancy and both families and young single professionals with careers in fields such as banking, law, education and medicine.

The building has two watchmen at all times, with one who does the day shift and another for the night-time, but these employees are changed regularly due to unreliability (as perceived by the residents) or to them returning home to villages. These watchmen sleep under the raised building. A sweeper woman visits once a day to collect rubbish from each flat and sweep the communal stairs and the car park. Each apartment employs a maid who visits for a short time each day and this same maid may be employed by several households in the same building or sometimes shared between the extended family, even if they live in different buildings. If the maid does not do the cooking (due to time constraints, lack of skills or caste), then a separate cook may be employed along similar lines to the maid, with wages negotiated individually. In our apartment there was a cook and a maid who both spent about one hour per day in the apartment, but also worked for several other households. Rainwater harvesting would be a good option for retrofit in this building because there is a highly differentiated water supply allowing the water to be used, but there is little impetus within the co-operative society as the water supplies are well managed.

7.3.2 Residence Two: Andheri (West)

The second apartment building is further north, in Andheri, and sits within a small colony of South Indian Hindus (buildings and whole areas are sometimes segregated along religious or ethnic divides (Punwari, 2003)). The residents are mainly traditional extended families of professionals. The grounds are large with mature trees and benches, and a small playground for the colony's children. Older residents promenade in the grounds every evening, making the outside spaces central to the social network.

The colony employs several watchmen and they live under the raised plinth of the apartment building I was living in. The everyday practices of the home can be observed there under the building, including cooking and eating, drying clothes, reading and sleeping. This reinforces the class boundaries at the same time as unsettling the idea of the home as will be explored later in this chapter (Fernandes, 2011). We did not employ a maid and, as there was not always someone present in the apartment, some of the socio-technical practices that rely on deliveries did not work.

This building has a very good water supply but each apartment has a tank to fill in case of planned shortages. The water filter in the apartment was broken and so drinking water was delivered in twenty litre bottles of packaged drinking water. This solution was suggested by the landlord who has bottled water delivered to his own home in an upper-middle class neighbourhood, so that no one in his household has to filter the water (the differentiation of water supply is also discussed in Section 3.6.2).

7.3.3 Residence Three: Hiranandani Gardens, Powai

The third of the apartment buildings is in the *Hiranandani Gardens* township in Northern Mumbai. The area is spacious and green, as Gandy (2009: 15) explains, "On the outskirts of Mumbai, a plethora of new elite housing developments is under construction that draws readily on pastoral imagery or aspects of ecological design such as Hiranandani Gardens or Kalapataru

Towers." The township is a relatively expensive place to live even though it is further from central Mumbai than other suburbs. Although *Hiranandani* is next to Powai Lake it has water shortage problems and the township goes beyond its compulsory obligations to conserve and treat water. There is an eco-hotel within the township and another under construction due to high demand. The waste from these is prominently sent to the vermiculture[22] garden to be composted. *Hiranandani* is a managed township, which makes it clean and tidy and free from informal settlements, which could be used as an example of bourgeois environmentalism in action (Baviskar, 2011). However, in the streets at the edges of the township one finds the planned hutments of the workers and the unplanned areas and workshops, a bit like going behind scenes on a film set and seeing how it is produced.

The building is one of the older ones in the township (as it was constructed about 15 years ago) and is a large one in a group of buildings planned and constructed together to share amenities such as tennis courts. The building is set back from the road in its grounds with parking beneath the building. In this building some of the residents can afford drivers who maintain and drive these cars. The residents of these larger apartments are executives and business people and some of them have live-in servants as well as maids who visit every day. Although the apartments are large this does not mean that there are more people living within them. Instead, due to the possibilities brought by education and wealth, the younger members of the family live elsewhere (often abroad).

Ranya (a resident) was convinced that there was a rainwater harvesting system for the *Hiranandani Gardens* building. However, the building manager (interviewed 09/02/2011) explained that there is no system in place and he doesn't think that rainwater harvesting is a viable solution to water shortage in the building because the water supply is not differentiated sufficiently and rainwater cannot be used for all purposes without intensive treatment. Wastewater is already recycled in central system mentioned above. Ranya told me (08/02/2011) that at the last society meeting

[22] In which worms are used to speed the composting of organic waste.

(Autumn 2010) in that building they discussed the idea of solar panels, but it was not thought financially viable. This suggests that environmental ideas are being considered, even if they are not being taken forward due to the cooperative society management process and the financial barriers to technology change.

7.3.4 Commonalities

The three descriptions given above provide an insight into middle class apartment life. Although every dwelling is configured and experienced in a different way, there are commonalities that can be drawn between the 20+ apartments visited, indicating normalised practices. Qayum and Ray's (2011) exploration of *The Middle Classes at Home* reinforces these findings. Although drawing on empirical work in Kolkata (a city in east India) many of their findings echo mine in Mumbai on the culture and materiality of the middle class home.

All the middle class apartment buildings visited employed watchmen in the grounds as guards and handy men. Each apartment employs a maid for at least an hour every day (apartments in the same block may or may not share the same maid as relationships of trust between maid and employer are often more important (Qayum and Ray, 2011)). The employment of servants is central to the creation of both middle class status and lifestyle (Varma, 2007). Additionally most households own a private vehicle and so all the buildings have a car park, usually underneath the building to save space and protect the vehicles. At least one resident of each apartment works (or worked) as a professional or businessperson. These commonalities are used within this research to define middle class housing in Mumbai (see longer discussion on defining the middle classes in Chapter Three).

The layout of apartments and use of spaces give an indication of boundary perceptions and relationships to water in the home. This was particularly observed through bathroom provision and position of televisions, both of which challenge the privacy of the bedroom. There was rarely a family bathroom; rather everyone had an en-suite (in an American style) meaning that guests have to go into the host's bedroom to use the bathroom. This also means the number of bathrooms is high in a city with limited space and water. The plumbing in these bathrooms has a tendency to leak and so an increase in the number of bathrooms could lead to an increase in water loss and water pressure, and contrasts with the provision of communal toilets in other parts of Mumbai (McFarlane, 2008b, Graham et al., 2013). The television is often in the bedroom rather than the sitting room, meaning that either members of the family watch television in separate rooms or all piled on one bed (Qayum and Ray, 2011) and both were observed during fieldwork. These practices change the nature of use of space, such as the bedroom becoming a less private place as it is used as a shared social space and as a corridor to the bathroom.

7.4 Cleanliness and comfort in middle-class apartments

The discussion and analysis of everyday domestic practices begins inside the middle class apartments. Mazumdar (2007) suggests that for some elites and middle class people Mumbai itself is experienced primarily through its interiors, with little direct interaction between the resident and the city outside, and this cult of the interior is simulated on screen in Bollywood films. This section unpicks the relationship between the resident and the apartment through the water practices carried out. The scene is set using ethnographic observations across several site visits. Several cleanliness practices are then explored as part of a socio-technical system, paying particular attention to the (sometimes contested) use of rainwater and the role of servants. Actions and technology choices can effect housing and create new discourses and practices of 'sustainability' in the city. High-rise living in India is a mark of some success, with new high-rise developments offering ever more amenities being constructed wherever space and planning allows. In this section of the chapter the middle class apartment is presented through its practices and interactions with rainwater harvesting.

7.4.1 Servants in middle class culture

Maid arrived at 9:15. She is wearing *salwar chemise* and jingling with bangles. Her necklace indicates that she is married. Her *chappals* have been left outside the apartment door and she does her work in bare feet (except for toes rings and anklets, again indications of married status).

First she sweeps the floors using a traditional broom. Then she empties the bins, putting them outside for collection from within the building. A bucket is retrieved from underneath my bathroom sink and filled with cold water and detergent. The floors are then cleaned using a cloth, starting at the other end of the apartment. The bucket is refilled several times.

The maid just opens doors and does her job. Leaves my bedroom door propped open.

In a rare move for a maid in Mumbai, she cleans the bathrooms too. Wastewater from the floor-cleaning bucket is disposed of down the toilet and used to clean the toilet. The rest of the bathroom is cleaned using water liberally.

Box 7.1: Excerpt from research diary 03/02/2011 (Hiranandani Gardens, Mumbai)

This captures the practices that a daily maid performs within a middle class apartment. Box 7.1 is my description of one of the daily visits of the maid who came to clean the apartment I was living in, and is typical of employment practices in Mumbai. Qayum and Ray (2011) present the relationships between residents and servants and how everyday practices of the home are managed and performed reinforces class divides in a 'culture of servitude'. They also discuss the engrained nature of domestic servitude in both the middle and lower classes and how the "…management of servants is folded into the management of the household" (Qayum and Ray, 2011: 253). Thus the interaction of residents with some practices of the home is experienced through organising servants to perform these tasks, rather than directly, complicating notions of socio-technical systems developed in modern Global North studies, where servants are rarely employed in this way (Shove, 2003a). The use of servants was still a regular feature in middle class homes in the UK a few generations ago but now, although a cleaner might be employed by a middle class household who are very busy or are incapacitated, an hour a week is usually sufficient due to the use of machines to do perform tasks such as washing the dishes and clothes and thus increase convenience for the middle classes (Shove, 2003a). Practices are influenced by social and cultural context as well as access to reliable technology.

The employment of domestic servants highlights some differences between Indian and Western household practices. One developer, who studied for his master's degree abroad, explained that having servants is something he missed during that time:

> "There's things over here that make your life a lot more comfortable. I lived in America for 2 years. I lived by myself. I was doing everything by myself, you know, so that didn't work very well for me too. I wasn't used to doing my own stuff but it was a good experience." Gaurav Monga, *EcoHomes* (Mumbai, 16/12/2009)

Although he struggled in a different culture of living due to not having engaged with the practices of the home in this way before, he felt he learned from the experience. He went on to contrast his experience in America with that at home in Mumbai:

> "The labour is so cheap you get used to all this, you know, it's so comfortable. We have a couple of people working at home and everything is just set the way you want it and you don't have to do anything." Gaurav Monga, *EcoHomes* (Mumbai, 16/12/2009)

It is these dual aspects of affordability and convenience that makes the employment of others within the home an almost universal practice for the Mumbai middle classes. Convenience is experienced through the use of labour, rather than labour saving devices. This has an impact on the culture of living, disrupting the boundaries of the home; "In particular, paid domestic work within the household bridges the private-public divide, bringing social relations of power (class, caste, race/ethnicity, gender) into the household, and mirroring and reproducing these within the domestic unit." (Qayum and Ray, 2011: 248). It could be argued that this is not merely reproducing these social relations within the home, but reinforcing them, and employing servants gives residents power and increased status. The water practices undertaken by the range of people employed within the middle class apartment block are spatially gendered: The outdoor spaces are masculine areas that are centrally organised by the building's management and male workers undertake these practices. In contrast female workers carry out indoor cleaning practices, managed by female members of the household. For Leela Fernandes (2011) the middle classes reproduce inequalities within itself along complicated intersecting lines of wealth, education, caste, religion and language. This leads to questions of whether the home creates or reflects the wider context and can be analysed as a symbiotic relationship and places tensions within apartments.

> Even though the resident is suffering some health problems, she is living alone with one servant and enjoying the tranquillity of the arrangement. Latika sleeps on the kitchen floor. The driver is on call every day and often waiting in the apartment or taking tea in the kitchen. An additional maid comes every morning for an hour to do the cleaning (mainly the floors and bathrooms). Latika is in charge of the occasional maid, thus the practices of cleaning the home are even further removed from the resident. The resident is very environmentally conscious and says she is telling the Latika every day to not use so much water, but with little effect and this is then passed on to the occasional maid who cleans the floors and bathrooms. Latika was about to return to her village to see her family. In her village the water must be collected and stored every day.

Box 7.2: Ethnographic notes from research diary

The interaction between Ranya, the owner and resident of a flat in Northern Mumbai, and Latika, her 24-hour maid (who has been with the family for 15 years), is an interesting example of how the practices of the home are lived. This arrangement is another example of the middle classes no longer dwelling within large extended families (see Section 7.2.1). The negotiation of practices and the governance of water use within the home (and resistance to this) affect consumption.

7.4.3 Washing the dishes

> When my maid was late, I got frustrated by the dirty dishes and ants crawling over them and so I washed the dishes before she arrived only to face her scorn and exasperation, rather than be thanked. The dishes are washed by the maid in cold water using solid dish soap and a cloth, or being wiped by clean fingers, they are then left to dry on the side.

Box 7.3: Excerpt from research diary (Mumbai 2010)

This demonstrates the importance of cultural context to everyday practices as my British way of doing the washing up did not match with the expectations Indian middle class practices (Halkier et al., 2011). If the maid washes and puts away the dishes and the cook (often the same person) does the cooking, it would be theoretically possible for a family to live in an apartment and not be part of those kitchen-based practices. The resident is less likely to purchase a dishwasher because the current practice already offers personal convenience, and so the use of people as part of the infrastructure process can have a direct effect on technology uptake. This exclusion from practices also distances the resident from how much water is used and how the process of washing up is undertaken.

At a Climate Change Community meeting of young career researchers with UN-Habitat in New Delhi (22/11/2009), P.S.Shodi described how everyday he told his maid to not use so much water to wash the dishes, she would reduce it (whilst being watched) then be using a lot again the next day. She wanted to use a powerful jet of water so that she could wash the dishes quickly and thus get to the next house faster. He had lost control over the practices in his home, whereas environmental issues drove his concerns, the maid had other priorities. The aspirations of some middle classes are shifting towards a more environmental outlook, but this is not a primary concern for servants. This leads to a mis-alignment between middle class aspirations and everyday practices performed by servants. These same environmental issues could also be impacting on the maid’s home life with water shortages, but were not her priority whilst at work. The interactions between these servants and the residents thus also become an interesting relationship between the residents and the apartment.

It should be noted here that dishes in Indian middle class homes are unlikely to be washed with rainwater, due to the uncertainty of consuming rainwater, as discussed below. However the use of rainwater for washing the floors or clothes can enable more of the municipal water to be used for washing the dishes and other purposes for which water was previously rationed. All the practices that draw water into their assemblage are thus entangled and inter-related.

7.4.4 Floor cleaning

Floors are washed by a maid everyday due to the high level of dust that settles on surfaces from open doors and even through gaps in the building fabric. These environmental conditions mean that cleaning practices vary from those that might be found in other locations. The floors are cleaned daily by the maid, using a cloth and a bucket of water, to keep the dust down. This is a normalised practice that can increase consumption in a similar way to the car washing practices in Section 7.5.2 (Shove, 2003a).

> "...we use this water for 24 hours for flushing and all. Floor washing. We can get more water. 24 hours." Mr Patel, *Seahill Apartment Building* (Mumbai 24/01/2011)

However, the practice of floor washing can be carried out using a fairly small amount of water.

> "I use two buckets of water to clean the floors in the entire apartment." Saalima, daily maid in *Hiranandani Apartment* (Mumbai, 08/02/2011)

In this building the water is also used for cleaning inside the homes, particularly the floors, and for cleaning the offices of the cooperative management. Thus reducing consumption of the mains water supply by changing sources, rather than practices, and changing the water that is metabolised through the same practice.

7.4.5 Laundry

> "Exactly what 'doing the laundry' means depends, in a rather immediate way, upon the technologies involved and upon contemporary understandings of what it takes to produce a pile of appropriately cleaned clothing." (Shove, 2003a: 120)

It was observed in many apartments that the maid washes clothes in a bucket (or sometimes bath tub) and dries them on the window railings (visible in fig.3.4). This method of washing clothes uses the least amount of water by limiting water consumption to one bucket. This practice reduces the effort for the resident (increasing convenience) and makes them less likely to invest in a washing machine. The relationships within the assemblage are finely balanced and can change the nature of the system or, in this case, prevent change. In households where there is a washing machine it was observed that it is still the maid who fills, runs and empties the machine. The washing machine adds a layer of complexity to the practice of washing clothes and brings electricity supply into the practice. This labour-saving technology can free up more of the maid's time to concentrate on other practices.

"Who does the wash and where they do it reflects our attitudes towards sex, work, and time" (Busch, 1999). The issue of who washes the clothes and where can have an impact on power relations within the home (Shove, 2003a). Laundry is done by residents using a washing machine in Western middle class homes, and the washing machine has shaped the practice of washing clothes (Shove, 2003b). Although the laundry is done for similar reasons to create similar results, the accessibility of technology and reliable electricity in the UK or USA, and the availability of cheap labour in India, leads to different sets of laundry practices (ibid.) If a servant is doing the cleaning and the cooking then they become part of the practices and part of the house and inhabit a contentious position in the socio-technical system of housing being neither resident nor material part of the apartment. Sending clothes to the *dhobi ghats* is still popular in the Mumbai and this further outsourcing of practices and stretching of boundaries will be discussed in Section 7.6.

7.4.6 Flushing toilets

One of the most popular uses for rainwater is for flushing toilets as the water needs minimal pre-treatment for this practice and almost every building that has rainwater harvesting was found to use the collected water for flushing. Chief Engineer at MCGM explains the use of the rainwater harvesting system retrofitted into his own apartment building:

> "The water is used all 12 months for flushing. 30% reduction in BMC water requirement. This means the water bill is also less. Money has been recovered in 2 years." Mr Kuknur, Chief Engineer MCGM (Mumbai, 10/02/2011)

That apartment building had been using BMC mains water for all purposes before the retrofit and 30% of that is flushed away. The economic emphasis shows a common rhetoric that it is not for environmental ideas or shortage motivations but to reduce costs. Water for toilet flushing is often supplied by borewells and so the substitution is really a change in the way that the well is recharged. The differentiation of water sources supplied to the middle class apartment means that different sources of water can be used for different practices, but it is not always a simple substitution in retrofit projects. The reconfiguring of apartments can lead to problems when trying to retrofit rainwater harvesting such as at the Kanti apartments, a large apartment block in Bandra, the plan to flush toilets with rainwater and recycled greywater had to be abandoned as too many of the apartments had moved their bathrooms. Originally all the toilets were supplied by one source and the sinks from another, but where the bathrooms had been moved, that water source could now be used for a sink and supplying this sink with rainwater would not be permitted. Thus the collected water is just used for the outdoor practices discussed below and creates a highly fragmented socio-technical system.

Nadia at Carter Road explained that when using rainwater drawn from the borewell, the toilet bowl must be cleaned much more regularly, as scum builds up quickly.

> "...you have to actually clean your pan every day otherwise it's... a slimly thing and over the days it kind of becomes scaly..." Nadia, resident at *Carter Road* (Mumbai, 24/01/2011)

This is due to the high particulate content of borewell water. In Mumbai maids rarely clean the bathrooms but are involved in many other cleaning practices using water and highlights the difficulties inherent in controlling nature. Only one apartment was observed where the maid cleaned the bathrooms on a regular basis. The flushing of toilets is a key use of harvested rainwater and is often a direct swap from an old well to the well recharged by rainwater. Particularly if it is a change from municipal water, then there is an increased build-up of residue, making more cleaning work (Kaika, 2005). Interestingly maids in Mumbai rarely clean bathrooms and I observed that this often becomes a task of female residents, meaning that a change to borewell water for flushing can lead to inconvenience for the residents.

7.5 Gardens, car parks and swimming pools

Harvested rainwater is often used for outdoor domestic practices around and underneath apartment buildings. These are separated from the indoor practices spatially and by the actors involved. This section discusses the practices using rainwater under, around and on the exterior of middle class apartment buildings. It draws on interviews with residents and servants as well as ethnographic observations from several site visits. General observations are that male servants undertake most of the outdoor practices and rainwater is often used plentifully to water garden, wash cars etc. Practices incorporating human and non-human actants construct the grounds of the building as a socio-technical system. These outdoor practices are ones that concern the whole building and are generally carried out by employees hired by the society and paid for through residents' subscriptions to the co-operative society. The outdoor spaces are masculine-dominated spaces with male servants carrying out the practices here under direction from the (usually male) lead residents in the co-operative society, and this also increases the number of actors in the system. Outdoor space is limited in Mumbai and so apartment buildings are constructed with an open ground floor to allow for parking cars. These servants (especially watchmen) often sleep under the plinth of the apartment block, again blurring the boundaries of the home and simultaneously claiming the building's environs as a masculine space.

7.5.1 Gardens

Space is at a premium in Mumbai and in newly constructed properties, only a certain percentage of the site can be built on (calculated using the Floor-Area Ratio allowed for that project) then a certain amount of the remaining space must be greenery. This has the benefit of a cooling effect on the microclimate and also allowing rainwater to soak into the ground. However it must be realised that these spaces are then behind locked gates and for the enjoyment of a select few. These green spaces can actually increase water consumption, as these areas then need to be intensively watered because large areas of the ground of new build projects are turfed, leading to high maintenance needs (Robbins and Sharp, 2006). Rainwater is used for watering gardens and the presence of rainwater harvesting leads to increased watering of the gardens and thus more, or more successful, green spaces. This is the building's public face and so important to the middle class imaginary and lifestyle security.

The maintaining of lawns despite water scarcity is not a solely Indian fascination and has drawn attention in North America. The flows of resources (water and chemicals) and creation of industry around the grass in the compounds of these buildings is hidden by the natural, literally green, gardens (Robbins and Sharp, 2006). The idea of the maintenance of lawns and grounds is largely to display a desirable lifestyle to their neighbours could be used to explain the maintenance of grounds around apartment buildings and the washing of cars to some extent (ibid). Lawns and plants are also key to the rainwater harvesting debate as collected water is often used to create lush garden areas that were not achievable without the extra water, and were observed at all the properties visited in comparison to buildings with no rainwater harvesting system. Allon and Sofoulis (2006) found that keeping gardens alive during droughts in Australia was a motivation for water recycling practices. The protection and improvement of lifestyle can be seen as a key component to the environmental technology agenda, and visible in the gardens.

Figure 7.2 Carter Road Apartment gardens on 8th February 2010 (Source: Author)

Figure 7.3 Carter Road Apartment gardens on 24th January 2011 (Source: Author)

The gardens at the Carter Road apartment building show the difference that harvesting rainwater can make. Nadia, a female resident on Carter Road, explained how the retrofitted rainwater harvesting system has affected consumption and gardening practices:

> "Where I used to tell the gardener – 'please, today don't water, water only once in three days, or once in five days' - now he does it merrily every day and he's happy." Nadia, Resident at *Carter Road Apartments* (Mumbai, 24/01/2011)

In the eleven months between visits to the *Carter Road Apartment Building*, the effects of this more liberal watering are seen in fig. 7.2 from February 2010 and fig. 7.3 from January 2011. The gardens at this property became visibly more extensive and verdant between visits. This greenery has the added benefit of cooling the microclimate around the building, making it more pleasant in hot, humid areas like Mumbai. It is possible to have greenery without increasing water demand as Dr Gokhale, rainwater harvesting consultant, explained how the gardens at the Kanti apartments also used to be limited but are now extensive. At the Kanti apartments flowerbeds are used as vertical reed beds to filter rain and grey-water allowing greenery to be present all year round without increasing consumption (see fig 6.7).

Site visit observations also underpinned that it is male servants who perform the watering of the gardens, either a dedicated gardener in large buildings and townships, or as an extra responsibility of the watchman as observed in smaller apartment buildings.

7.5.2 Car parks

Older properties and some areas of new builds (which don't have exclusively underground parking) have car parks around and underneath the apartment block. This tarmac or concrete is regularly washed to remove detritus and dust, and rainwater is used in buildings with a harvesting system. The watchman was generally observed to undertake this, often with direction from the society secretary or president. However the sweeping of the grounds was observed being undertaken by male servants at one large apartment building and by the bin lady in some of the smaller developments demonstrating that status and caste (not just gender) have a role to play in who is part of which practices. This hard ground is one of the problems leading to depleted ground water as it prevents soakaway and allows the water to run into the sea, or create flooding.

Cars and other vehicles that are parked on this hard ground are also washed or wiped everyday due to high levels of dust in the city. In most middle class households a family member drives the car or scooter but some employ a dedicated driver. A driver is often employed so that the resident can make productive use of the long commute to work. Unlike the watchmen, most drivers live somewhere else and pick up the keys to the cars in the mornings of days when they are needed. One resident in *Hiranandani* has a driver on call on his mobile throughout the day. Another couple have bought their driver a scooter so that he can get into work quickly and not be late in the mornings. The practice of cleaning cars was observed in residential car parks being carried out by the (male) driver if there is one employed by the household, otherwise by the watchmen of the apartment building, first thing in the morning before cars are driven a resident's workplace. Mr Patel, a resident from *Seahill* apartment block (that has retrofitted rainwater harvesting) exclaimed on the amount of water used in the practice of cleaning cars:

> "Look how many cars are there – so it will take one bucket, daily for one car for washing." Mr Patel, resident at *Seahill Apartment Building* (Mumbai, 24/01/2011) [translated from Hindi by Mr Singh Bedi *Osmosis* rainwater harvesting consultant]

Car washing is carried out daily as dust accumulates rapidly in Mumbai. Rainwater is used for this practice, when it is present, and water is used sparingly with a cloth and bucket but adds up, as Mr Patel points out, to a large amount of water when performed for each car every day. Shove (2003a) argues that high frequencies of washing are often unnecessary but have become normalised practices that increases consumption.

7.5.3 Swimming pools

Swimming pools are sometimes filled with rainwater (although as they are outdoor, they would fill up in the monsoon). In new build projects, swimming pools are almost always included as a selling point such as *Palais Royale,* which was under construction when it was visited, and is set to have several swimming pools. Rainwater harvesting will be installed as a mandatory measure and included in the LEED assessment, in which it is expected to do well. This is an indication that even as 'green' credentials are applied, consumption may increase. The use of 'green' infrastructure enables greater consumption by providing more water, which can raise expectations of water provision. The *Kanti Apartments* also have a swimming pool filled with rainwater but this is rarely used.

Figure 7.4: Rarely used swimming pool filled with harvested rainwater, Kanti Apartments, Mumbai (Source: Author)

Dr Gokhale (interviewed 07/02/2010) suggested the under-use of this swimming pool could be due to its position as it is overlooked by many apartments, as shown in fig 7.4. This is one use of rainwater harvesting that goes beyond previous consumption levels and so is another example of ways in which rainwater harvesting can be seen as allowing increased consumption of water for lifestyle status gains (Fernandes, 2011). Use of water for practical and necessary uses, such as drinking and sanitation, is in conflict with provision of water for symbolic value, such as gardens and swimming pools (Kaika, 2005). Harvested rainwater can be used to replace other water sources for essential practices and help others in the city with water shortages, by reducing the demand from those apartment buildings from the municipal water supply. However, it is often used to provide additional water for access to extra water resources though rainwater harvesting is for those who have collected it, thus it can be seen as providing lifestyle security and improvements for residents.

Watering gardens with collected rainwater can increase water consumption as there is no longer a need to water sparingly with scarce and expensive municipal or tanker-delivered water and in this way the middle class lifestyle is secured. This has led to lush green gardens surrounding many buildings with rainwater harvesting, which is good for well-being and for the microclimate but is an example of an environmental technology being used to facilitate increased usage rather than conserve resources. Swimming pools also show rainwater harvesting as being used to facilitate increased water consumption and increase status within the middle classes rather than replacing other sources and reducing overall consumption. Changing expectations of provision from new sources and increased quantities of water supply can increase consumption and be at odds with environmental strategies (Shove et al., 2008). The differentiated water supply, with one specific supply for outdoor practices and a specific set of outside actants and technologies also leads to a separation between this system and the inside of the home that is not merely spatial.

7.5.4 Exterior maintenance

Everyday practices are not the only ones that use harvested rainwater. An apartment building on Carter Road was being repainted and harvested rainwater was used to wash down the walls and mix the paint, giving an insight into how the rainwater supply is used in building maintenance.

> "…whilst they were painting [the exterior of the building], they had to actually be like, you know, wash it and scrub it so they used the same water [the harvested rainwater]." Nadia, Resident at *Carter Road Apartments* (Mumbai, 24/01/2011)

This is an interesting additional application of the rainwater to conserve resources and save money whilst expensive maintenance work is being undertaken. This practice echoes the use of rainwater on construction sites, where it is installed first to provide water for construction (see Chapter 6). The use of rainwater in the maintenance of this older building can be seen as an extension of this practice and a very literal way in which the outdoor space is constructed by practices using rainwater harvesting.

7.6 Stretching the boundaries of housing

> "The bourgeois home operates as a blissful private shelter insofar as it is selectively sealed from the outside world" (Kaika, 2005: 70).

Allowing the maid into the apartment is part of the *selective* sealing of the boundaries of the home. Fig 7.1 shows a maid's sandals outside an apartment, from which one knows that the maid is inside. All residents and visitors to an apartment in Mumbai remove their shoes, but maids and other workers leave their footwear outside the door in the corridor or stairs. If we consider the house in socio-technical terms, it begins to question what we consider as a house, particularly the boundaries. Kaika (2005) sees the bourgeois home as sealed off from the world but this may not be the case in all situations. Rachel Whiteread's *House* sculpture (referenced by Kaika, 2004) was a concrete cast of the inside of a house and helps me explore the idea of boundaries[23]. The walls were removed from the house leaving the solidified spaces that once were the voids of the home. The cast was defined in its form but the points where the infrastructure was accessed were there in negative cast pushing their way into the solidified spaces (Corrin, 2001). The house without its skin, and yet still a house, open to the elements. The presence of servants blurs the bounded edges of the home, linking the space where the servants live to those where they work (Dickey, 2000). The boundary of the home is not the rigid line but a more porous membrane that allowed in other actors and is intrinsically linked to the city via the infrastructure flowing through it and to nature.

The boundaries of the home are not rigid and impermeable but effected by wider culture and selectively permeable to other people and materials (Dickey, 2000). The idea of selectivity is important here, the borders of the middle class home are permeable but in the controlled manner allowing certain flows into the private spaces and out again but still maintaining ownership and privacy (Kaika, 2005, Qayum and Ray, 2011, Dickey, 2000).

[23] Whiteread's *House* won the Turner Prize in 1993 before being demolished by the local council

The apartment is conceptualised as a series of processes, rather than the static concrete walls that bound it or even the rooms within, and these processes intersect to form the socio-technical system of the home. Some of these practices, forming the system, take place outside the apartment or people who live outside the walls are part of the process. This section aims to interrogate this permeability through the use of servants and how their dwelling places outside the middle class residence begins to stretch the boundaries. The practice of out sourcing clothes washing is also used as an example to address the stretching boundaries of the socio-technical system.

7.6.1 Co-operative housing creates permeable boundaries

A simple example of the permeable nature of the middle class Mumbai home's boundaries is that through the co-operative housing society each individual home is interlocked with others in the building or complex. As well as joint maintenance and improvement decisions, households may also share domestic servants. However, owning a flat outright is becoming more popular, especially in new large high-rise apartment blocks that attract younger nuclear families. So this cooperative society culture of living may not survive the westernisation of Mumbai housing for future generations. Viewed through a western cultural lens, this permeability in the flows of resources and the admittance of friends and workers seems like an invasion of privacy (Dickey, 2000). However, for the Indian middle class this permeability is normalized. People regularly permeate the boundaries of the home to perform practices, as well as resources coming from various sources and certain practices being entirely outsourced. The boundaries can thus be seen as not merely permeable but malleable as the system stretches to include regular workers and the outsourcing of practices, such as washing clothes (Kaika, 2006, Dickey, 2000).

7.6.2 Maids stretch the boundaries

Some of the reasons for employing and bringing additional people into this socio-technical system were discussed in a previous section, here, the spatial motivations and the effect this has on the boundaries of the apartment are considered. It is cheaper, easier to hire a person than to purchase several machines to aid the same practices (a dishwasher, a washing machine and a vacuum cleaner for example)(Shove, 2003a). Critically for this discussion, maids usually dwell elsewhere meaning that they do not take up precious space in the apartment as machines would. Does the place where the maid lives become a part of the middle-class residence in some way? The presence of servants in the home questions the boundaries of the home and connects it to other places:

> "I work for one hour in this flat and then clean a beauty parlour. When my daughter [about 8 years old] is not in school I bring her." Saalima , daily maid, *Hiranandani Apartments* (Mumbai, 08/02/2011)

Most of the maids who visit apartments daily to clean them live in nearby slums, as Saalima does. There was some concern, voiced by Charu* and Sherina* (sisters living in different apartment blocks in Bandra) that as slums were about to be cleared for redevelopment this would mean that either their trusted maids would have to travel much further, or they would have to find new maids. The preference was to retain the long-serving maids, but there was concern over whether this would be possible. Nadia mentioned the problems that her maids report from the slums in which they live:

> "All our maids come from there [nearby slum], and they are always complaining. Last three days they just didn't have any water. Like they just had water for barely two hours and they just had a queue for one tap and a whole lot of… so she said "all that we managed to gather was drinking water" so it's just no bathing, no other. Just bare essentials. So it is a huge problem." Nadia, *Carter Road Apartments* (Mumbai, 24/01/2011)

Severe water shortages are impacting on life in the informal settlements of Mumbai, and middle class residents are aware of this but also highlights how the banal practices of the home are not banal for the whole population (Gandy, 2008). As mentioned above, water shortages at home are rarely reflected in a maid's work. The place where the maid lives can be seen as a part of the socio-technical system of the middle class home. This section and

* Names changed for anonymity. Information from personal communications.

the previous one have demonstrated the gendered nature of water practices and of the space of the home. They have also begun to unpack some of the justice implications of water practices, which are further explored in the subsequent section through the contested nature of rainwater as potable water. The number and extent of servant employment in India is high and hiring servants can be used as proof of middle class status and provide the convenience and lifestyle desired (Qayum and Ray, 2011, Dickey, 2000, Varma, 2007). This outsourcing means that it may be the servants who are most aware and in control of resources, and they could be more aware of environmental impacts on water supply in their own home lives. In Mumbai many of these servants live in informal settlements with limited access to water and sanitation (Gandy, 2008, McFarlane, 2008b). Some of the male servants may reside underneath the apartment building, but again have very different access to water. The interactions between these servants and the residents of the houses, also becomes an interesting relationship between the residents and the house.

7.6.3 Practices beyond the walls but part of the assemblage

One of the watchmen at the *Sealine Apartments* has been there for twelve years and has seen the transition from shortage of water and tankers before to plentiful supply now there is rainwater harvesting. The *Sealine Apartments* share rainwater with neighbours in times of need and they give buckets of rainwater water to the drivers from neighbouring buildings to clean the cars most days. This sharing of decentralised infrastructure retrofitted into one building to be used for practices at several buildings brings them together in novel ways and stretches the systems boundaries again.

Washing clothes is an example of how different ways of performing a practice can change the nature and boundaries of that system. Consider all the ways that clothes washing can be achieved: machine wash, hand wash, laundrette or *dhobi ghats*. The *dhobi ghats* are a place where some households send clothes to be manually washed by male *dhobis*. The garments[24] are collected in bundles and delivered on bicycles to the *dhobi ghats*, which are rows of open water troughs often a long distance from the residential building where the garments are collected. The clothes are then dried in the sun at the *ghats* or elsewhere (and sometimes ironed). Thus this outsourcing changes not just the locations and system boundaries but the techniques, infrastructure and the gendered nature of washing clothes once outside the apartment walls.

Figure 7.5: Clothes drying on the beach (Source: Author)

Interestingly in Bandra/Khar the clothes are sent on bicycles to the Carter Road beach to be laid out to dry (fig. 7.5), after being wash at the *dhobi ghats*. This shows the multiple uses of space in Mumbai as when the sun goes down, the middle classes promenade next to where their clothes may have been dried and are unknowingly walking through their washing cycle. Some households send out all their laundry, whilst others will only send certain items to be washed at the *dhobi ghats*. This is another example of the stretching of household boundaries by the flow of practices being performed remotely and using infrastructure that would otherwise be unconnected to the apartment. A service seen necessary by the residents of a house, and in

[24] The clothes are labelled on the inside using a system of symbols so that they can be identified and returned to the correct house once clean and dry.

many instances, particularly in the west, undertaken in the home, can be externalised as a practice of convenience. This externalisation of services leads to a questioning of what we consider to be a house. If the laundry is sent to the *dhobi ghats*, this place, its human and non-human actants, become part of the home system. Whereas the person who wears the clothes is further distanced from the practice of clothes washing.

In other ways the boundary of the home assemblage in Mumbai is very tight, with the inside of the home immaculate and clean and the dust and dirt accumulating just outside the door, where the maid has left her *chappals*[25] in fig.7.1. With more people living in high-rise apartment blocks this is a very tight boundary indeed, but the cooperative nature of housing management caters to help govern this situation.

7.7 Bathing in and consuming rainwater: class segmentation of water access and practice

> "Through the process of division of labor and the allocation of different spaces to different users (stratified by gender, age, status, etc.) the social and gender inequalities, power relations and violence that were meant to be kept outside became reproduced within the 'ideological prison' of the private space of the home" (Kaika, 2005: 63).

This section discusses the final set of water practices to be unpacked in this chapter; those that involve drinking water, or applying it directly to the body. Potable water sources vary between households and the people who access them depending on the water supplies and interactions but this can lead to varying effects on the environment and on power and justice. The sources of drinking water in the middle class home are presented as a starting point for this discussion but whether rainwater can be used for potable purposes seems an ambiguous and loaded question. Rainwater may

[25] Sandals

be one of the purest water sources in Mumbai but the knowledge of where it has come from, coupled with the way it is stored and treated, make it an undesirable source of potable water for the middle classes. Rainwater harvesting could be used as part of the solution to this infrastructural shortage but this is currently banned (Pandey et al., 2003). The restrictions in the water supply are made graver by the presence of the 'water mafia' in Mumbai. Bathing practices are also related as they also use potable water and again the use of collected rainwater is contested by middle class residents and this reticence is backed up by legislation preventing the use of rainwater for these purposes. The justice implications, of who has access to the different sources of water for different practices, are played out through this interrogation of rainwater harvesting uses revealing how water access is segmented along class boundaries. These personal bodily uses also emphasise the residents' role in the socio-technical system.

7.7.1 Bathing practices

Bathing in middle class bathrooms in Mumbai is still usually a bucket bath, using one or two buckets of water filled from taps on the wall with water heated in a 'geyser' (electric water heater), or via solar thermal water heating. A few bathtubs were observed but they were rarely used once the children of those households had grown up and then the bath is only used by maids for washing clothes. Showers are often installed to create wet rooms, but many residents still prefer to use buckets and a jug. This method uses less water than showering or filling a bathtub and is promoted by the municipal corporation (see Appendix 5). This bathing practice differs from those favoured in other countries, for example Shove (2003) explains that daily power showers are now the most popular bathing practice in the UK.

Rainwater could be used for bathing, but it is not usually done because legislation is in place to prevent harvested rainwater from being used for these practices. Mr Singh, a rainwater harvesting consultant, explained that at the building being visited the rainwater was not used for bathing due to legislation even though he believes the water to be of high enough quality,

> "BMC don't allow because bacteria. But in emergencies, they can bathe also. Quality of water is very good." Mr Singh, *Osmosis*, Mumbai (24/01/2011)

The rainwater might get into the mouths of children when they are bathing:

> "No for bathing we use BMC water because you know, it's like a little bacteria and it's not good and there's kids. And if they ingest it…" Nadia, at *Carter Road Apartments*, Mumbai (24/01/2011)

Thus rainwater is not plumbed into the bathroom taps or shower. This again questions the purity of rainwater, which most children will have got in their mouths in monsoons, but because most rainwater is used to recharge borewells and then withdrawn at a later date, it is perhaps the status of borewell water that is in question.

7.7.2 Drinking harvested rainwater

Figure 7.6: Sign above recharge pits and borewells at the Carter Road building (source: author)

Drinking water is technically supplied to the middle class Mumbai home from the central MCGM supply which flows to each area of the city for a few hours a day (see Section 3.6). Newly constructed buildings are not connected to the BMC supply unless they have installed rainwater harvesting system first (As discussed in Chapter 5). This water is often stored in tanks on the roof of apartment buildings to be used throughout the day and monitored by the watchman. Few middle class homes use BMC water directly for drinking and cooking, as it is not considered pure enough; instead it is filtered through an ultra violet filter above the kitchen sink and stored until use. *Aquaguard* is how these filters are referred to and this is actually the brand name of water purifiers of the market leader, *Eureka Forbes.* The Eureka Forbes Institute of Environment initiated a project of: 'Rain Water Harvesting in Urban India' with special focus on Mumbai. The objective is to create citizens involvement in working out a solution to the Water crisis' (Eureka Forbes Institute of Environment, 2011) and it was information from Eureka Forbes that encouraged residents in one older Hiranandani building to retrofit rainwater harvesting. Once water has been filtered for consumption it is usually stored in drinking bottles or metal urns. In one apartment I visited the drinking water was stored in a traditional earthenware *matka* pot to keep it cool, blending new technologies with traditional techniques. Whether the water really needed to be filtered is debatable, but it has become a normalised practice within most middle class homes.

7.7.3.1 Inequalities in access to drinking water

The middle class household is able to buy itself out of reliance on the state provided water for drinking purposes. Some households bypass the BMC water for drinking (and the need to own and operate this water filtration device and the maintenance that is then required) by having drinking water delivered in 20 litre bottles from the mineral water giant *Bisleri*, who have a bottling plant in Mumbai. *Bisleri*'s tagline is 'The sweet taste of purity', thus positioning itself as safer, healthier and even better tasting than the state provided water. Bisleri has similar aims and values to other packaged drinking water companies and is used here as an example due to its plant in Mumbai and its success at promoting itself as a regular supply of water at home. *Bisleri* presents the vision of: "An India in which every person has uninterrupted access to scientifically purified and fortified drinking water, irrespective of geographical barriers or economic limitations" (Bisleri, 2011). Presenting itself as the solution to India's water issues is an unrealistic move as this is a relatively expensive way to gain access to drinking water, even if it does not require the capital investment of the filter. One drawback for some households is that this potable water source means that someone must be home during office hours to accept delivery, as I discovered in one apartment with a broken water filter. This highlights the traditional use of extended family living and/or hiring of servants, which results in someone being home for a large proportion of the day to accept delivery of such items. The social part of the system has more weighting in Mumbai. The power to choose the source and supply of drinking water and to ensure the quality of water for your family is a privilege not open to everyone (Gandy, 2006b, Swyngedouw, 2004). This use of other sources to provide drinking water or filter the regular supply can be seen as methods to increase resilience in that household, but the effect is to lessen demand on the BMC water supply and to decrease pressure on the BMC to improve its supply reliability or quality. Many others in Mumbai have very restricted access to any water, and obtaining drinking water is particularly difficult and expensive and not always safe (Gandy, 2006b). It is not uncommon for maids or the bin lady who visits to request water to drink when they are in middle class homes as they have difficulty accessing water, particularly water of drinking quality.

In the *Secret Building*[26] the residents did not drink the harvested rainwater, but they had supplied the area where the servants cooked and ate with a tap supplying rainwater so that they could consume the water. This underlines the perceived societal differences between residents and servants, and what resources are suitable for whom for each purpose within the system. Although this water is likely to be cleaner and safer than some of the sources in Mumbai, it is not seen as acceptable by the middle classes in this particular building. Harvested rainwater is used as potable water by the middle classes in extreme circumstances, or when a special filter is in place.

> "One is the suspended matter is higher. The content of suspended matter, it comes from there. The second is that the bacteria count is a little higher." Navin Chandra, *Sealine Apartments*, Mumbai (24/01/2011)

[26] The residents in this building were particularly reclusive and would not permit interviews or photographs of the building to be taken.

At *Sealine* they have a series of filters, including a UV filter, in place to supply potable water in times of extreme water shortage. With the correct storage and/or treatment there is no reason why harvested rainwater cannot be used for all purposes (Pandey et al., 2003, Handia et al., 2003).

The everyday water practices using rainwater harvesting illustrate the power dynamics of the Indian middle class home. They highlight the injustices of water provision by who performs a specific task and who has access to which water sources for their personal use, as shown by the reluctance of middle classes to consume rainwater, but allowing servants to do so. The use of rainwater as a source of potable water is a controversial issue. Although it can be one of the purest sources of water, the methods of collection, storage and treatment are vital to maintaining the quality. As this quality cannot be guaranteed the precautionary path is taken of not consuming the water, or even using it for bathing, except in times of severe water shortage. However there is evidence of the water being made available for servants to drink and cook with rainwater, using the status of resources to reinforce power.

7.8 Conclusions

In this chapter everyday water practices have been explored within the Mumbai middle class home to begin to unpack how rainwater harvesting is experienced and performed. This chapter has used empirical data to explore the home through different everyday practices, and established human agency in these assemblages. Water practices in Mumbai's middle class apartments have demonstrated that these practices are complicated through the inclusion of human elements, especially those employed as servants and as workers in outsourced practices. These inclusions distance the resident from the property and pierce and stretch the boundaries of the home. The role of servants has been central to this socio-technical analysis and to the creation of middle class status itself.

The distancing of the resident from the practices of the home by the employment of servants is an issue that has been raised throughout this chapter as an extension of the socio-technical theories of the home as it can have an impact on practices and thus on the home itself. This distancing can also affect the uptake of technologies, as the purchase of effort-saving technologies would pass on the benefit to the maid. There may also be a limited awareness of water use practices. Resource saving devices may not be considered by a resident who is not experiencing, or directly in control of, resource use and consumption. The choices made by the homeowner or resident, such as installation of new technologies or bathing practices, make a difference to the possible environmental impact of the home and its resilience to water shortage. Shove (2003) discusses convenience and normalised practices as being driven by technology developments and the 'black boxed' infrastructure systems that provide services. However empirical data from Mumbai has revealed in this chapter that these interactions are complicated by the differentiated infrastructures and the use of servants. The convenience of Mumbai's middle classes is provided for residents through the use of servants, reinforcing class divides.

It has been observed that residents who have installed rainwater harvesting are often then inspired to retrofit other environmental technologies (such as solar water heating) when the transition pathways have been opened up (see Section 6.7). However, the distancing of the residents from the resource use of everyday practices can be a barrier to technology adoption, as the resource consumption and hard work are not experienced directly. Thus the servants are pivotal actors in the Mumbai middle class home. The use of servants also adds flexibility to the provision of services as people can adapt to change rapidly (Simone, 2004). This use of people as infrastructure also allows for flexibility and resilience, for example maids washing clothes by hand or people delivering water rather than pipes, whilst reducing direct energy demands and the rainwater collected is often used for tasks performed solely by these servants.

Changing technology, such as water source to rainwater harvesting, is alone not enough to create environmental water practices. Improved water supply can in fact increase consumption to secure and enhance middle class lifestyles. Water shortages from the municipal supply have led to each apartment being supplied by different water sources to create water supply security. The differentiation of water supply also allows for adaptation through technological retrofits, such as rainwater harvesting. This is because the new water source can be used to supply just certain taps, and thus used for only a limited set of practices. Thus the water for certain practices does not need to be filtered to a potable standard. The outdoor practices around apartment buildings have been used to highlight this. Improved environmental awareness of residents is also not the solution alone for domesticating responses to water shortage and environmental issues, as culture and normalised practices are important. In the Indian middle class home changing the perceptions of the residents is also not sufficient because servants have other concerns and normalised practices. The everyday normalised practices of the home can in fact be barriers to change. The above discussion has shown that it is when the technology and the concepts come together to change the normalised practices of the home that climate change is addressed domestically.

Chapter Eight

Conclusions: Domesticating environmental infrastructure

Figure 8.1: *Assemblage of governance, everyday practice and apertures* (Source: Detail of original mixed media artwork by the author)

8.1 Meeting the research aim

The aim of this thesis is *to assess how Mumbai's middle classes are responding to environmental change through rainwater harvesting*. I have explored rainwater harvesting in Mumbai's middle class apartment buildings through socio-technical concepts to reach this aim. This research shows that water infrastructure interventions are mainly within the apartment buildings that comprise middle class housing in Mumbai's suburbs (Shetty et al., 2007, Qayum and Ray, 2011). I found that Mumbai's middle classes are retrofitting rainwater harvesting systems in response to water shortage and environmental change. Rainwater harvesting is also being installed in new build properties to replenishing ground water in response to mandatory requirements form the local government, and this can help reduce local flooding as art of a sustainable drainage plan. I have used housing typology to define my study group of Mumbai's heterogeneous middle classes as and I am adding to the literature on this under-researched heterogeneous group.

I have taken three slices through the empirical evidence to analyse how rainwater harvesting is governed, assembled and used in middle class Mumbai. In this chapter I take up the aim by drawing together threads from across the thesis to demonstrate how the three research questions have been addressed and that the contributions of this thesis go beyond the answers to the research questions. I discuss key findings of the thesis in further detail and related to the debates that this thesis sits within. I then present the limitations of the study with suggestions of further research to address these issues. Dissemination strategies and policy implications for these findings are suggested at the end of the chapter.

8.2 Addressing the research questions

Research questions have moulded both the empirical methods and the theoretical approach, and thus I revisit them here to illuminate the key research findings. Each question is interrogated directly in this section to draw out the implications for the research and to consider how rainwater harvesting is governed, assembled and used.

8.2.1 How is rainwater harvesting governed in Mumbai?

Debates on governing the environment have focussed, to date, on national and international scales, and more recently at the city-level (Bulkeley and Betsill, 2003, Hodson and Marvin, 2012). In this thesis I have used rainwater harvesting as a lens to look at the ways in which housing is being constructed as a site of governing environmental issues from the city level to the individual. Housing is a nexus of infrastructure and is becoming a site of service provision. Legislative interventions by the state mean that rainwater harvesting is mandatory for all new apartment buildings in Mumbai (Municpal Corporation of Greater Mumbai, 2003), as discussed in Chapter Five. Water management is also being taken up by developers seeking to enter the 'green' market. These developers may also use assessment schemes to guide and accredit the environmental aspects of their buildings. The Government of India and the Government of Maharashtra are experimenting with green assessment schemes tied to tax incentives. Middle class urban residents are also installing rainwater harvesting into existing buildings with the help of rainwater harvesting consultants. Thus interventions into middle class housing are occurring through rainwater harvesting both as retrofits and in new build apartment blocks.

A governance reading has allowed the analysis of the diffusion of power and interrogation of the different tools and modes of governing. The middle classes are reacting to the water shortages by installing rainwater harvesting to secure their lifestyles, and often to save money, but at the same time understanding the environmental implications. Developers are implementing environmental technologies to attract clients and to meet the criteria set by the municipality. In turn the municipality are, on the one hand, pursuing a more environmental strategy of infrastructure provision and, on the other, rolling back their responsibilities of provision. This reduced responsibility of the state co-produces resilient middle classes, in turn normalising shortage of mains supply and feeding back into the new role. The building of resilience of the middle classes could be used by the MCGM to shift responsibility for water provision onto all residents. This could have serious justice implications for the urban poor who already struggle to find enough water and are unlikely to have the means to secure more water through rainwater harvesting.

The public provision of water in Mumbai is inadequate with no 24 hour provision anywhere in the city (Gandy, 2008). In this thesis I have suggested that one way in which the municipality is addressing this infrastructure deficit is by re-casting housing as a provider of its own water services. The main intervention is the mandatory requirement that new domestic buildings have rainwater harvesting installed. This removed some pressure from the centralised system and could lead to a rolling back of the municipality's responsibilities for provision. However, the inclusion of one environmental technology in legislation can lead to other technologies being included, and housing supplying further services, such as energy, which could further address infrastructure deficits. Private companies, such as builders and developers, are installing environmental technologies to appeal to purchasers and are increasingly turning to assessment schemes to guide these decisions. This research has uncovered assessment schemes as a crossover point between the public and private actors in governing housing. National and state governments are beginning to experiment with assessment schemes as a tool for governing housing (Municpal Corporation of Greater Mumbai, 2009b).

The private governance, at the individual and building level, relates to retrofits in existing buildings and so it separated from the two other scales of intervention by site as well as actors. Middle class housing in Mumbai is usually apartment buildings run as private co-operatives who manage changes in service provision (Ganapati, 2008). Governing at this level reinforces the new role of housing as rainwater harvesting systems are retrofitted to create water provision. This produces a resilient middle class who can cope with, and accept, shortage of provision from the state. These communities are able to secure their services and lifestyle, but poorer citizens do not have the capacity to retrofit systems. Thus this normalisation of shortage can have an adverse effect on water provision for the poor by allowing the state to roll back provision, although it also has the potential for more equitable distribution.

8.2.2 How is rainwater harvesting assembled and installed in and around middle-class domestic buildings?

The answer to this question varies between systems, in particular new builds and retrofit configurations, which have been identified as the different contexts involving different sets of actors. I identified three main types of rainwater harvesting in Mumbai: the first fills a tank and directly replaces water delivered by tankers (during the monsoon season at least), but this is usually used in conjunction with another system; the second replenishes the ground water, and this improves the amount of water available to withdraw with a well at that property. This is the system preferred in retrofits; the third system is favoured by developers and is the recharging of the groundwater to meet legislation but without the later withdrawal of water for use. The water may be withdrawn elsewhere however. In this section I consider: how systems are delivered; the maintenance and its implications for the systems; and whether installation is contested.

As I conducted analysis on the initial data I uncovered connections between rainwater harvesting and other technologies within buildings and the city. Using assemblage concepts as a framework of analysis allowed me to understand the installation and incremental changes through maintenance but lacked insight in the directional change occurring and the interactions between technologies. Thus I used a combination of assemblage and socio-technical transitions approaches as a framework to understand the directional changes that appeared to be occurring at several levels. In Chapter Six I demonstrated with the use of empirical evidence that, in some middle class apartment buildings in Mumbai, the installation of rainwater harvesting led to the installation of other domestic technologies that can be used to address resource shortage.

Rainwater harvesting is sometimes the first element to be installed on a new building site to help supply water for the construction process, by collecting rain that falls on the grounds, as explained by Sanjay in Chapter Six. Being installed first along, with other services, means that other structures do not obstruct the installation. The apartment building can also be designed to optimise rainwater collection from the roof. Conversely, retrofitted systems can be complicated by the existing building obstructing, or altering, the assemblage or by objections to installation. The retrofitted system must fit around and into the building, grounds and residents' practices rather than shaping it from the beginning to become part of the socio-technical system. Taking an assemblage approach to understand the delivery of rainwater harvesting systems has allowed me to consider not just the heterogeneous elements but also the process as a whole. The assemblage approach I have taken here has illuminated the stages of design and installation through the elements and their interactions. This analysis of interactions provides insights into changes as rainwater harvesting systems transform from discursive ideas and plans to a material system, through processes of translation and disassembly and reassembly. These processes of change continue through processes of maintenance.

Maintenance of the system depends on the configuration and elements in the assemblage and using an assemblage lens to consider maintenance allowed me to consider it as a transformative process. Maintenance varies between assemblages, with some needing daily attention such as adding chemicals (as seen at the *Secret Building*) and others needed yearly disassembly to clean the filters (as observed at the *Sealine Apartments*). Contestation of rainwater harvesting is rare due to the financial savings possible, however in retrofit projects there was evidence that some residents might oppose installation. In some retrofit projects the co-operative leaders decided on installation without the need for approval of all residents as it would not affect the inside of the property, as at the

Bandra Colony. However, there is some question over whether functional systems are being installed in all buildings (Kulkarni, 2012). Some developers may not be installing working systems, demonstrating that legislation alone is not enough to enact change.

8.2.3 How is harvested rainwater used in middle-class homes?

The differentiation of water supplies to Mumbai middle class housing allowed harvested rainwater to be used for particular practices. The main uses of the water were found to be flushing toilets, cleaning cars and floors, and watering gardens. The practices that water is not used for by the middle classes are also important in the discussion for two reasons: firstly, more water is available for these practices due to the use of rainwater; and secondly it highlights uneven distribution and access, especially when servants are allowed to bathe in or consume rainwater. In times of extreme water shortage, the middle classes might use rainwater for bathing and drinking, as discussed in Chapter Seven. In new buildings rainwater is often percolated into the ground in order to improve ground water levels in the area, and meet the minimum requirements set by the municipality, without first being used in other practices.

The boundaries of the home are stretched and perforated by both the bringing in of servants who dwell elsewhere and have other commitments and the outsourcing of practices (Kaika, 2005). The example of laundry has been particularly useful in exploring outsourced practices. The sending out of clothing and bedding to be washed, dried and pressed outside the home is common amongst middle class Mumbai residents. This practice stretches to the boundaries of the socio-technical system and further reduces the control of the resident over the practice and the resource use.

This thesis has shown the installation of rainwater harvesting is often to secure supply and thus the lifestyle of the middle classes, allowing practices to be undertaken even in times of water shortage. In some instances rainwater harvesting has been shown to increase consumption through watering gardens and filling swimming pools to display the middle class lifestyle. The rainwater is not metered as it goes into the ground, or as it is withdrawn, and so there is no monitoring of whether the same amount, or preferably more, water is being put into the ground than withdrawn by any system. The unbounded nature of many of the rainwater harvesting systems also means that the position of the water replenishing the groundwater is not known, and so the water could be being withdrawn elsewhere.

The use of rainwater harvesting to create a plentiful supply, and maintain or improve middle class living, challenges the concept of rainwater harvesting as an environmental response to water shortage and places it within the performance of what it is to be middle class. Rainwater harvesting can be used to maintain non-necessary water usages during water shortage, rather than saving water for the household or the city at large. Rainwater harvesting has the potential to ease pressure on the piped water system by decreasing the water consumption in households with harvesting systems, but it often seems to increase consumption of water for luxuries. Thus a rhetoric that relies on changing the ideology of residents and encouraging installations of technologies such as rainwater harvesting may not have a significant effect (Shove, 2003a). Both the social ideas and the technical possibilities encourage uptake of environmental technologies when they are in alignment and working together. However, in middle class Mumbai housing the everyday practices can create barriers to uptake or subvert installed technology to increase consumption.

8.3 Distinctive contributions of the thesis

Mumbai was chosen as the site for investigation because of its status as a global and mega city, as well as its vulnerabilities to climate change, which correlate with many coastal cities in Asia and the wider Global South (Yeung, 2001, Hodson and Marvin, 2012). This means that some of the findings of this thesis, with due caution, could be applicable to other urban areas. This thesis makes three key contributions to knowledge that are discussed here in more detail. Firstly, housing is being repositioned as a water supplier, and thus a site for governing services, promoting middle class responses to shortage and allowing the municipality to roll back provision, leading to justice issues for the urban poor. Secondly, the domestication of water supplies through rainwater harvesting can accelerate the uptake of other environmental technologies within residential buildings by creating apertures in the socio-technical transition. Thirdly, rainwater harvesting facilitates the performance of middle class lifestyles by securing constant water supplies but servants can distance residents from resource use and influence uptake and effectiveness of these decentralised environmental services. Therefore the domestication of water infrastructure through rainwater harvesting has the potential to open up homes to become more sustainable if we acknowledge the complexities of interactions in residential buildings.

8.3.1 Housing as service provider

Mumbai's housing is being re-cast as a provider of services, primarily of water through rainwater harvesting interventions. This new role repositions housing as a governance conduit and domesticates water infrastructure. This finding makes a contribution to literature on governing infrastructure and could have policy implications for Mumbai and other cities. In this thesis I have also moved away from the North-centric energy focus within environmental debates, to add to understanding of water infrastructures in Mumbai. The state is reinforcing this new role of housing, with residents as producers and consumers of decentralised 'green' resources, through rainwater harvesting legislation and other initiatives. I have argued in this thesis that the new role of housing is allowing the state to redefine its role as service provider, and roll back its responsibility for universal provision. Private middle class residents are working to the same logic to secure their water and energy supplies by retrofitting systems. The rolling back of the state's water provision shifts the responsibility for governing water resources to the residents, reconfiguring their role to become both consumer and supplier. The domestication of water provision is also leading to the rescaling of the generation and governing of energy resources within residential buildings. This decentralisation of resources redefines residential buildings' relationship with the city and the boundaries of infrastructure.

Retrofits are important for the new role of housing presented in this thesis due to their role in creating resilience and forming a new level of privatisation. As the middle classes collect and supply their own water they form a new type of localised privatisation, which feeds back into legislation and shifts power, governances and changes the relationship with the city. Thus housing's role as a site of environmental response and service supply needs to be re-accessed. The new role of housing has implications for the scale at which governance of both infrastructure and climate change responses is understood and enacted. Infrastructure governance is domesticated as housing becomes an important site of water infrastructure governance and the middle class residents gain more control over their water supplies. The repositioning of service provision inside domestic buildings fragments decentralised infrastructure, further opening up possibilities for a more flexible and resilient service. This enables privatisation down to the scale of individual buildings and private actors.

The new role of housing has thus co-produced middle classes that are resilient to water (and energy) shortage and to some aspects of climate change. By accepting this new role of housing the middle classes normalise the shortage of municipal water supplies, drawing on the capacity of the resilient middle classes to address the infrastructure deficit and prioritising their supply over poorer communities. This rescaling of provision down to the building and creates resilient middle class households. However this emphasis on middle class responses to water shortage and environmental concerns has justice implications in a city where 60% of the population live in informal settlements with reduced water access and lower resilience. This stance should not be used to justify a reduction in per capita water supply.

8.3.2 Apertures in socio-technical transitions

I have explored technology uptake to show that one technology can open up spaces or apertures allowing other technologies to be 'fast tracked'. If one technology works successfully, then other technologies can pass through the space in thinking and behaviour created by the first technology, as well as making use of material spaces formed in a building. I have termed these spaces *apertures* and see them working as portals to catalyse the uptake of technologies. This process is made possible by the new role of housing as service provider, and reinforces that logic. Rainwater harvesting is creating apertures that facilitate the uptake of other environmental technologies and accelerate transition towards a more sustainable urban future in Mumbai. This adds to socio-technical transitions literature, both in the understanding of the individual transition and the interactions of different technologies and the intersection of their transition pathways.

This finding makes a contribution to socio-technical transition theory, by adding to our understanding of how the transition pathways of technology uptake might influence each other. Rather than acting in isolation, the transition pathways charting the uptake of technologies into the regime intersect at different points in time. If one technology has followed this pathway, then an aperture can be passed through as a shortcut in the transition. The aperture's role in the transition process towards more sustainable housing has been observed most clearly in retrofits, but it can be seen in other systems, although often at different temporal and spatial scales. Crucially this can give an insight into methods for speeding up socio-technical transitions, by making use of apertures created by other technologies in a specific site, and has implications for governance. The apertures created by environmental technologies could be used within governance to guide transition.

8.3.3 Middle class residents are distanced from practices

The employment of domestic servants to perform everyday practices distances the resident from some of the material and maintenance aspects of the home, and this can have an effect on the uptake of technologies as the resident would not directly interact with them. Thus labour saving devices, that may also save water, energy or detergent but could increase consumption, are unlikely to be purchased by a household that employs servants, because there would be no direct benefit of convenience to the resident. This resonates with Shove's (2003a) understanding of practices in the home and their relationship to environmental issues but extends them through the context of Mumbai. Everyday water-use practices were shown to be particularly complicated by the employment of servants that distanced the residents from practices in two ways: firstly by distancing the resident from the material aspects of the home; and secondly, the servants have different priorities from the residents.

Servants, especially daily maids who have additional time pressures, have divergent needs and ideas from residents about how to undertake domestic practices. This research has shown that this can lead to a loss of control over the practices by the resident. The installation of environmental technologies is not enough to ensure environmental practices, as the influences in the lives of those carrying out practices is different from those deciding to install the system. These technologies must also be embedded in an environmental ideology to be translated into sustainable practices. A socio-technical reading of the home and responses to water shortage brings together the social and the material in these practices (Shove, 2003a). This analysis has shown that there is some misalignment in the system of the middle class apartment, creating a barrier to technology uptake and transition to a more sustainable future. This finding makes a contribution to literature on everyday practices, which often focuses on Western modes of being, by extending the scope to look at household practices in Mumbai.

8.4 Limitations and research possibilities

This investigation has been limited to one section of Mumbai's society by the timescale and resources of the PhD process. The focus on the middle classes is important in adding to the knowledge about this under researched, but growing, section of society and their relationship with infrastructure and the environment. There is potential for further research considering different housing typologies and other classes of resident to widen understanding of infrastructure governance. As assessment schemes are taken up by the Government, it would be interesting to investigate this further to determine the success of the scheme and its effects on the governance of housing and raising awareness of environmental issues.

Discovering these interventions within buildings was problematic, as discussed in Chapter Four, due to the hidden and private nature of many responses and the lack of environmental language around projects. This research did not consider religion and caste in its investigation, and this may have limited the analysis of power distributions and dynamics, although as Nijman (Nijman, 2006) points out these are not necessary considerations when looking specifically at Mumbai's middle classes. The nuances and sensitivities surrounding these concepts make them difficult to study, especially for the foreign researcher. These limitations could be addressed in collaboration with local researchers.

The unwillingness of middle class residents to participate in this research, and especially the difficulties in researching with the servants of these residents, has reduced the capacity of this research to interrogate everyday experience of harvested rainwater. This limitation was addressed to some extent using ethnographic methods, as discussed in Chapter Four, but a more in depth study of residents and servants would increase our understanding of how everyday domestic practices interact with technology uptake.

The concept that one technology is pivotal to the uptake of other technologies in a certain situation is a major finding of this research. However, this investigation has been limited to middle class housing in Mumbai where rainwater harvesting is performing this role. In other cities and situations, it could be a different technology that is acting as a catalyst and creating apertures. Further research in a variety of cities and systems could add to this socio-technical understanding of change and how transition pathways relate to each other. In extending the research in this direction a focus on South-South knowledge transfer could be encouraged and could have implications for the governing of resource provision and environmental issues.

8.5 Policy implications and dissemination pathways

Dissemination of research findings has been an important part of the thesis writing process. The CASE partnership with BSHF may facilitate the dissemination of my findings beyond academia but this pathway limits outreach in India. I have therefore sought other ways to have impact within the communities I have researched. Union Park, an area of Mumbai that features in several chapters of this thesis, has set up a community radio station 'Jago Mumbai' ('Wake Up Mumbai'), and I was given the opportunity to be interviewed and present some of my ideas about sustainable housing in Mumbai, which were recorded and played on the station. This was an interesting way to engage in community dissemination to a large local audience in the local community. There may be opportunities to feedback further findings into this community using these outreach mechanisms.

The affiliation with *Rachana Sansad Architecture School* allows some opportunities for dissemination and I was involved in assessing some design work for sustainable apartment blocks, allowing me to draw on my knowledge of environmental technologies in Mumbai. I will be sharing some of my findings with the school for use in design projects. Architecture draws on cultural knowledge and practical implementation, and this thesis can contribute to environmental building design in Mumbai through an understanding of how technologies are installed and the effects of everyday practices, and could influence practice through education in architecture schools. The artwork in fig. 8.1 at the beginning of this final chapter is an attempt to visually represent the ideas within this thesis and was made as an alternative to a poster for a symposium. The piece is an assemblage that depicts both the empirical findings and some of the theoretical concepts of the thesis, including socio-technical concepts of governance, everyday practice and apertures.

Policy implications from this thesis create a potential for further impact. Housing can be used as a conduit for the governance of infrastructure provision as they are re-cast as suppliers of their own water and energy. This re-scaling and joining up of approach could have implications for urban environmental policies. However, considering housing as a service supplier shouldn't justify limiting supplies in the future, especially in a city where many do not have access to adequate housing or water supplies. Following on from this, the installation, or legislation, of one technology can catalyse uptake of other technologies and this has implications for academic debates and policies of environmental response to resource shortage. However, I have also identified that legislation and technological interventions are not enough to create domestic environmental responses and that a combined socio-technical approach is needed.

Appendices

Appendix 1: Interviews

Name	Organisation or building	Notes[ϕ]/ website	Interview date(s)
Shyam Balsekar	Linear Technology	Technology supplier.	06/11/2009
Adolf Tragler	Sum Rehabilitation Society	www.srsindia.org	11/11/2009
Sanjay*	Developer	Gave me tour of building	12/11/2009
Brinda Somaya	Somaya and Kalappa Architects	Renowned environmental architect. www.snkindia.com	18/11/2009
	BMTPC	www.bmtpc.org	22/11/2009
Zeenat Niazi	Development Alternatives NGO in Delhi	www.devalt.org	22/11/2009
Roshni Udyavar Yehuda	Head of Department of Environmental Architecture Rachana Sansad	Architecture school became my affiliate organization on my second field visit. http://enviorment.rachanasansad.edu.in/index.php	24/11/2009 13/02/2010 15/12/2010 01/02/2011
Gaurav Monga	EcoHomes	www.ecohomesindia.com/htmlsite/general/index	16/12/2009
Gaurav Shorey New Delhi	TERI (The Energy and Resources Institute)	www.teriin.org/index	30/12/2009
Ajit Gokhale	Grey water and rainwater consultant		07/02/2010
Navin Chandra	Sealine Apartments, Jago Mumbai	Met Navin many times. Gatekeeper for several other projects and provided contacts to consultants and others. www.jagomumbai.in	09/01/2010 08/02/2010 22/11/2010 02/12/2010 08/12/2010

[ϕ] Interviews in Mumbai unless otherwise stated. Most interviews conducted in respondent's office or during building visits.
* Name changed for anonymity.

			09/12/2010 14/01/2011 20/01/2011 24/01/2011 07/02/2011 12/02/2011
Seema Redkar	MCGM	www.mcgm.gov.in	14/02/2010 20/01/2011
Chaitanya	Architect	Wants to set up green architecture practice.	
Amar Joshi	Rainwater harvesting consultant and geologist	Interviews on first visit and tours 3 buildings on second visit www.amarjoshi.com/index	20/02/2010 14/01/2011 25/01/2011
Uma Adusumilli	MMRDA Chief Planner	http://mmrda.maharashtra.gov.in/index.jsp	24/02/10
Nadia *	Carter Road Apartments* resident	Visited same building one year apart to see progress	08/02/2010 24/01/2011
3 residents	Union Park	Informal discussion.	
Jonathan Stock	Mumbai Dialogue	www.dialoguegroup.co.uk	23/02/2010
Email communications	TCP-India	Manufacturers of chemicals www.tcpindia.com	
Koyel. Email response.	Institute for Financial Management and Research	www.ifmr.ac.in	
Akshay & Aditya	7 Greens	www.7greens.in	22/11/2010 02/12/2010
Bharati Kakkad,	Union Park Residents' Association (UPRA)		02/12/2010
Mayank Gandhi	Remaking of Mumbai Federation	www.romf.org	03/12/2010
Rajiv Mishra	Sir JJ College of Architecture	www.sirjjarchitecture.org	03/12/2010

2 researchers	Saatchi & Saatchi	They were on a fact finding mission on green issues in India	08/12/2010
Deepak Visvanathan	Habitat for Humanity	www.habitatindia.in	09/12/2010
Sonal Alvares and colleagues	Environmental Management Centre	www.emcentre.com	15/12/2010
Mrs Mankar*	Resident, Bandra (w)	Involved in tree planting.	17/12/2010
Prasad Modak	Environmental Management Centre	www.emcentre.com	28/12/2010
Sen Kapadia	Sen Kapadia Architects	Renowned environmental architect.	29/12/2010
Ashok B. Lall New Delhi. Telephone interview	Architect	Famous environmental architect. www.ashoklallarchitects.com	10/01/2011
Bibek Bandyopadhy ay ,New Delhi	Ministry of New and Renewable Energy (MNRE)	www.mnre.gov.in	11/01/2011
Alisha*, New Delhi. Telephone interview	Delhi Resident	Was involved in arranging installation of rainwater harvesting in her colony	11/01/2011
Prathima Manohar	Urban Vision	Urban Vision disseminates information about urban projects but these usually have an environmental slant	21/01/2011
Gurjeet Singh Bedi	Osmosis	Rainwater harvesting consultant	24/01/2011
Osmosis Assistant	Osmosis		24/01/2011
	Colony president in Bandra	About to install rainwater harvesting	
Hiren Bhagat	EDS	Environmental consultant at 'Science Park'	25/01/2011
Priya, Deepak, Mr	Triratna Prerana Mandal (TPM)	Society in Mahim slum area that has installed rainwater harvesting	01/02/2011

Jadhav, Dillip Kadam			
Dayanand Govind Nohite and his wife	TPM and MCGM	Resident of TPM building and worker for MCGM. His wife is president of the women's group	01/02/2011
Anant Palkar	Hiranandani Environmental Engineer	Discussed the history of the township's development and systems and the motivations for undertaking them. Environment is his special interest so he oversees it as extra responsibility	04/02/2011
Brinda Ayer	Hiranandani resident and Eco-Housing consultant	Helped IIEC to make EcoHousing guidelines appropriate for the different climatic zones of India	08/02/2011
Suprabha Marathe	MCGM rainwater harvesting	Adamant that most of the things that I need to know can be found on website	10/02/2011
Mr Kuknur	MCGM chief engineer	Gave details about how the systems are checked for. And revealed that they have retrofitted RWH in his building/society.	10/02/2011
Ranya*	Hiranandani resident		08/02/2011
Latika*	24 hour Maid		08/02/2011
Saalima*	Maid	Works at several properties – flats and a beauty parlour. Translated by employer.	08/02/2011
Building Manager	Hiranandani Apartments*		09/02/2011
Matias Echanove	Urbz	Discussed general issues of urbanisation in Mumbai: Money	04/02/2011
Mr Patel*	Seahill Society President	Translated by Osmosis consultants	24/01/2011
Priyanka*	Hiranandani Gardens resident		04/02/2011
Mr Daniel Chatterton	Rodas Ecotel Manager	Eco-Hotel in Hiranandani, Powai	11/02/2011
Rucha	Rodas Ecotel	One the environment team	11/02/2011

Malesh*	Rodas Ecotel	Knew nothing of environment before employment at hotel	11/02/2011
Basudha*	Watchman at Sealine	Brief discussion translated by employer.	12/02/2011
Hiranandani Engineer	Works for Palkar Anant	Toured Hiranandani Gardens looking at the different RWH systems	04/02/2011
Atasi*	Hiranandani Resident		14/02/2011
Atasi's father	Hiranandani Resident		14/02/2011
Viral	Yes bank and Hiranandani resident	Sustainability consultant at Yes Bank. Phone interview	14/02/2011
Shetta	Hiranandani resident at Lake Homes		14/02/2011

Appendix 2: Site visits

Site	Gatekeeper and key people	Building and technologies info	Date(s)
Sealine Apartments, Bandra	Navin Chandra	Low carbon' technology retro-fit and education programme and consultancy RWH, then solar heating then PVs and vermicomposting	09/01/2010
	Watchman	Great tour looking at the technologies and having them explained. Chance to ask questions to Navin Chandra. RWH, solar-thermal, vermicomposting and PVs.	
		Key case study showing retrofit of technologies starting with RWH. The project may also have led to the larger initiatives of Union Park and Jago Mumbai as well as to other buildings installing environmental techs (esp RWH)	

Carter Road Apartments, Bandra	Navin Chandra Nadia*	RWH is only technology so far but they are considering whether to include more technologies. One family owns the whole building. Navin Chandra consulted on the building's rainwater harvesting system. They are now considering other technologies that could be retrofitted. Saw the system one year on and found that it had worked fine for the year. They are considering solar and maybe wind next, as they are on the sea front. Currently using water to wash down whole building and for repainting the building. Progression from Sealine. Get to talk to resident who led project. They are considering installing other techs now.	08/02/2010 24/01/2011
Large Developers Building*, Mahalaxmi	Developer Sanjay*	Seems to present the low-carbon rhetoric but deliver little. Safety is major factor in design Looking at some environmental things but failing to see in what way it is really 'eco'. The developer got creepy during this. RWH definitely working but then they have a swimming pool. Service floors and escape routes are a good measure. Example of new build but probably of the 'greenwash' or misunderstanding that is going on	12/11/2009
EcoDale, Andheri	Research assistant, Jasmine	RWH, solar heating and fly-ash blocks (developer-led new build) Chased out of the building by an angry tenant after getting a disinterested response from the society secretary. It has RWH and used fly ash blocks. Architect no longer practising or in the country. New build. Again a disappointing show of 'greenwash' rather than a deep green ethos and subsequent buildings have LESS eco-measures rather than more	09/01/2009

Palais Royale, Lower Parel	CTBUH tour	Low-carbon approach to get LEED certification but also includes vastu ideology India's first 'green' residential project. Provisionally LEED platinum rated. Concrete mono with emphasis on concrete rather than eco-techs. Vastu principles written in a concrete tower. They seem to be holding their cards close to their chest and not answering my emails. Example of new build that is striving for LEED accreditation. No photos allowed.	05/02/2010
Kanti Apartments, Bandra	Ajit Gokhale Consultant	RWH and grey water recycling Retrofitted grey water recycling through flowerbed to create a vertical reed bed system. RWH system had also been installed. Ajit Gokhale showed me and explained the system. Another retrofit scheme that shows the importance of one individual in initiating a scheme. It also displays that the response can be elegant. Highlights some issues of retro-fit - such as reconfigured flat layouts	07/02/2010
Secret Building*, Bandra	Ajit Gokhale Consultant	RWH and grey water recycling Ajit Gokhale was the consultant here as well. Small system for treating the rainwater and bath water, some of which is recycled into the servants quarters (as well as watering plants and washing cars etc) – building must be kept secret on request of those living there. Another retrofit combining RWH and grey water recycling. Highlights who looks after the system and its uses	07/02/2010
Fatepur Sikri, Uttar Pradesh		RWH and design. Historical example Ancient building complex of religious significance that had RWH and natural ventilation. It also uses traditional pierced marble screens and shaded walk ways to further make the climate inside the complex usable. Ancient buildings like this could be used as inspiration for modern passive architecture.	20/12/2009

Habitat Centre, New Delhi		Uses some passive techniques to make a very pleasant courtyard. Open but shaded and microclimate controlled using trees and ponds/fountains. It is also a mixed use complex with good transport links, but it is also an exclusive club for corporations dealing with habitat issues. Passive office building group. Shows what can be achieved when buildings are considered together to create modern passive design	23/11/2009
Seahill, Bandra	Osmosis Resident, Mr Patel*	This is the building which has the radio station on the roof. RWH done because of shortage. They will be supplying grey water to the former BMC garden. The radio station is to be converted to run on renewable energies. RWH system was undergoing the yearly cleaning maintenance, which is supplied by Osmosis. Routine maintenance was being carried out by the consultant's men.	24/01/2011
Bandra Colony, Bandra	Osmosis	Retrofit of large system to cater for several buildings About to install rainwater harvesting as the site currently floods and water just flows out from sloping site. The already have borewells and ringwells but not getting enough water as on hard rock. Just about to install, so displays the beginning of a retrofit. Surveys needed. Differs from other projects as it is on solid rock needing boring	24/01/2011
15th road, Bandra	Osmosis	Retrofit. The digging of pits for filtration was going on, by hand, when I saw the project. Digging itself will take 3-4 days by daily paid workers. Then the whole system will take about 25 days to be installed. Initial stages of digging on display.	24/01/2011

Goregaon SRA, Goregaon	Dr Amar Joshi	Terrace system as the grounds are very dusty and car covered. The system was being installed during the visit. This gave me a chance to see the lay out and working of the system. Should have had RWH to start with as it is a fairly new building but the builders paid their way around it Halfway through installation process. As people did not want disruption, a lot of the terrace water is brought round the building above ground in pipes	25/01/2011
Lokhanwala, Andheri	Dr Amar Joshi	This is a new build township with RWH installed from the beginning. They have been working with Amar Joshi from the beginning when he did the survey for them. Say they haven't gone for solar etc because they think that the residents wouldn't care and wouldn't look after the system New build, that has been incorporating RWH for years. Could be useful comparison with Hiranandani. But they don't seem to be moving towards other 'green' techs due to barriers of upkeep	25/01/2011
Nirlon Knowledge park, Goregaon	Dr Amar Joshi	This is largely an IT park. They are going for LEED rating on each phase as it attracts foreign multinationals. The campus was very calming. Water is used to cool the surroundings which are very green. http://www.nirlonltd.com/green_campus.html Not residential but showing what can be achieved. Views on rating systems useful.	25/01/2011
Triratna Prerana Mandal (TPM) SRA,	Priya from TPM	RWH used to flush toilets form water collected from garden/play area and community centre roof. Very grass roots organisation. The toilets are part of the housing for a slum Considering solar for lighting and computers Example of how RWH can be used to benefit low income families. Also helps thinking on where the boundaries of the home are	01/02/2011

Hiranandani Gardens greywater recycling, Powai	Mr Palkar	Township with centralised grey water recycling from the beginning. Now new buildings are given separate treatment facilities Tour with engineer to see several buildings and the central sewage treatment plant (STP) which is hidden in a park. A couple of the commercial buildings are LEED rated. The campus also has an ecotel and is building another. Tall buildings are residential and low-rise are commercial. Goes beyond what is mandatory (ie to part treat waste water and sewage before giving it to BMC) by fully treating sewage and re-using 80% of the water. There was some resistance to this recycling at first, but now it is seen as benefit apparently	04/02/2011
Hiranandani Gardens RWH, Powai	Engineer	5 different RWH methods were shown at both the township level and that of individual buildings Tour with assistant engineer. To 5 different sites around the township. RWH taken up by builders before legislation - check what is needed for townships though	07/02/2011
Union Park former BMC garden, Bandra	Navin Chandra Potential solar consultants	Grey water and solar. The garden has been taken over form the BMC. It sits on rock so it not good for RWH recharge so instead grey water from a nearby building will be used to water plants. Solar is going to be used to power lights etc. it will be a demonstration of what can be achieved. Links to Sealine. Interesting ways to solve the problems with the rock underneath	02/11/2010 08/12/2010

Residence	Comments	Dates
1: Bandra Apartment	Shared apartment with young professional female Indian. Employed cook and day maid	Nov 2009-Feb 2010
2: Andheri Colony	Shared with young professional female European. Did not employ servants, but the colony did.	Dec2010-Jan 2011
3: Hiranandani Gardens Apartment, Powai	Lived as paying guest within small household. Maids and driver employed by residents.	Jan2011-Feb 2011

Appendix 3: Conferences, meetings and workshops

Name/ date	Summary
Climate Change Community Meeting UN House, Delhi 22/11/2009	Dr Jalan, P. S Shodi and Dr Sollon all presented as well as representatives from ICLEI. The UNDP's Solution Exchange was also discussed as a network for environmental professionals.
CTBUH World Conference, Mumbai 03-05/02/2010	This conference brought together a variety of people from across the world to discus buildings and urban habitats, with a particular emphasis on 'sustainability'. Interesting in-sights into Indian and global opinions on tall buildings and sustainability. Particularly enlightening were the chairman telling all the Mumbai developers to stop building tall buildings until the infrastructure is in place and the thoughts of Charles Correa (Indian architect) on density not height, amenities and passive design
Mumbai Dialogue, Mumbai 23/02/2010	Bringing together British and Indian architects and developers. The presentations were mainly form the British perspective, which was rather disappointing and not how the promotion had made the event sound. Encouraging to see sharing of ideas but I have the feeling that it was largely for the benefit of Brits who want to break into the market in Mumbai
Eco Housing Conference and Exhibition, Mumbai 16/02/2010	One-day conference organised by the Government of Maharashtra and the Institute of Self-Governance. It was very interesting that these issues are being considered at such a high level but unfortunate that the presentations were mainly in Indian languages. The Gov. Of Maharashtra is to bring in EcoHousing and that making sustainable housing is important to them

Rachana Sansad 50th Anniversary Symposium on 'Learning in Cities', Mumbai 01/2010	Variety of topics covered and good to see what is currently happening in the Mumbai architecture scene. This included some information on sustainability issues but not in as much depth as I would have liked. Overview of interests in the architecture scene of Mumbai
Eastern Waterfront Debate. JJ Architecture School 01/2010	Development possibilities for the Eastern Waterfront in Mumbai are discussed and debated.
Slums Seminar, Pukka, Mumbai	Interesting for background information and understanding of the city of Mumbai. Book *Dharavi: Documenting Informalities* is thought provoking about the city of Mumbai and about how we record and research neighbourhoods and housing
ALM regional meeting, Bandra, Mumbai 11/12/2010	Brought several community groups together to discuss future way forward
National Conference on Green Design: Buildings and Habitats, New Delhi 07-08/01/2011	Focussed largely on the GRIHA rating system but also looked at other aspects of green building in India (and beyond) providing an overview of what is happening in India on the green building agenda Ministers, architects, technical advisors and product suppliers came together. Was co-hosted by MNRE and TERI.

Appendix 4: Survey for Architects

Housing and the Environment | Cat Button, Durham University

Survey of Architects

I am researching housing and environmental technologies in Mumbai. I am interested in the point of view of architects on environmental issues, which I find to be an over-looked area. If you can spare 10 minutes, I would be grateful for your responses to the following questions:

Name:

Architecture Practice:

Email:

1. How did you become interested in environmental architecture?

2. Does your architectural work use any 'green' technologies or ideas? Which?

3. Is climate change impacting architectural responses in Mumbai? If so, how, and if not, then why?

4. What effect do you think voluntary target systems (such as LEED, GRIHA or GreenHomes) have on the industry?

5. What do you think is shaping housing provision in Mumbai?

6. What effect is government legislation having on housing and on environmental measures?

NB. By filling in this form you agree to the use of the information in academic writing. Any data used will be presented anonymously. If you have any questions about my research, please do not hesitate to contact me. Many thanks.
Cat Button, Durham University. Email: c.m.button@durham.ac.uk Tel: 9930526036

7. What do you think could be done to encourage environmental architecture in Mumbai (and India in general)? What are the barriers to uptake?

8. Do you know of any environmental housing projects in Mumbai?

Other comments:

NB. By filling in this form you agree to the use of the information in academic writing. Any data used will be presented anonymously. If you have any questions about my research, please do not hesitate to contact me. Many thanks.

Cat Button, Durham University. Email: c.m.button@durham.ac.uk Tel: 9930526036

Appendix 5: MCGM Advice on Domestic Water Conservation

बृहन्मुंबई महानगरपालिका

Water Conservation at Individual Level

Individual Checklist :-

1. Use small size glasses for drinking water.
2. Make habit of serving glass & jug for a group of people.
3. Left out drinking water in glasses should be used for watering the plants. Water used for washing vegetable, grains is good for plants.
4. 'Yesterdays' water is not stale, it is good for plants.
5. Never open the taps completely, open them half or three forth.
6. Plastic nozzle in the tap reduces water consumption considerably.
7. Make a habit of using mug & bucket for brushing, bathing, washing utensils & cars. (Showers if used shall be closed while applying soap.)
8. In rural area one full family will meet its daily or even weekly demand by the water consumed in one bath tub.
9. Make a habit of utilizing full capacity of washing machine for every lot. Washing two lots together saves 40% water when semi automatic washing machines are used.
10. Washing machine wash water can be reused for rinsing dirty clothes, utensils, floors & flushing.
11. Dual type flushing cisterns 5/10 lit. to be provided in toilets or two filled up plastic 'Mineral water bottles' to be places in the existing flushing tank to reduce its capacity.
12. Balconies & common passages can just be swabbed instead of washing them by pouring lot to water.
13. Promptly repair leaking water taps, pipelines, prevent overflowing of tanks. Ball cocks (flow control floats) in tanks are a must or adopt pump with level switch arrangement.
14. Avoid unnecessary paving.
15. Indigenous plants retain soil moisture much better.
16. Do not pollute ground water sources by dumping waste in it.
17. The garden can be watered or cars, staircase & common passages can be cleaned with well water wherever it is available.
18. Use rain water for secondary purposes during monsoon.
19. To maintain ground water table recharge the well/bore wells by Rain Water Harvesting.

REMEMBER

WATER IS PRECIOUS NATURAL RESOURCE & NOT COMMODITY
USE JUDICIOUSLY. RE-USE IT EFFICIENTLY.
WATER CONSERVATION IS NOT JUSE A HABIT IT IS A CULTURE.

Appendix 6: MCGM Rainwater Harvesting Information Leaflet


CATCH WATER WHERE IT FALLS
Government of Maharashtra issued directives under Shivkalin Pani Sathavan Yojana* to various Municipal Corporations for taking up Rain Water Harvesting in their jurisdiction. M.C.G.M. held discussions with various professionals & by order of Municipal Commissioner, set up a study group under Chairmanship of Additional Municipal Commissioner (P). First meeting of the study group was held on November 15, 2002 wherein it was decided to formulate Rain Water Harvesting cell to study various aspects of RWH & to initiate Pilot Projects in M.C.G.M. Premises.
*G.R. NO. RPD/1001/CN/ 330/WS-07 Dtd. 14/2/2002.
Storage of Rain Water in underground or above ground Artificial Tanks
Santacruz Transport Garage
Purpose: Carwash & Gardening
Roof Top collection. Tank above ground for direct utilisation and with pump to fill up over head tank.
Recharge component not considered as in flood prone area.
Gutter
Filter
R.W. Downtake pipes
First Flush
Direct Recharging of the Subsoil Water Strata through Dug Up Wells
Bhagavati Hospital
Purpose: Flushing & Fire Fighting
Roof top collection for direct use & dug up well recharge. Intermediate level collection tank. Surplus for recharge. Surface runoff for gr. Water recharge by percolation pits
Filling Pt. for fire brigade.
Mun. Water Tank
R.W. Downtake pipes
Percolation pit.
Perforated paver blocks
Recharge well
Mun. Water Tank
First Flush
Filter
Source well
With open Tap
106 Lit
With Mug
2 Lit
Remember
12 Litres of Water
is Wasted in 1 minute
Through open Tap
With Shower
80 Lit
With Mug & Bucket
20 Lit
CATCH WATER WHERE IT FALLS
Rain Water Harvesting has been made mandatory to new developments having plot area 1000 sq.mts. and above, from 1st October 2002 by introducing an IOD condition and checking compliance prior to issue of O.C.
Till June 2010 about 1651 new buildings have implemented such projects. This activity is monitored by building proposal department of Brihanmumbai Mahanagarpalika which controls development activities. From June 2007, RWH has been made mandatory to new development having plot area 300 sq. mtr. and above.
Recharging of the Subsoil Water through Percolation
Sane Guriji Udyan
Purpose: Gardening
Siddhivinayak Mun. Garden.
Daily demand - 30,000 lit.
One ring & two recharge wells. Surface runoff for gr. water recharge. Mun. supply disconnected since Nov.04.
Saving Municipal Water 1,00,00,000 Lit./Yr.
Recharge Structure
Ring Well
Direct Recharging of the Subsoil Water Strata through Bore Wells
C.T.I. & R.C. BORIVALI
Purpose: Gardening
Roof top collection for direct use & bore well recharge. Saving in cost of gutter by providing vata. First flush valve & online filter. Bore well did not dry after monsoon 05.
Mun. Water Tank
R.W. Downtake pipes
Bore Well
Recharge Structure
Recharge well
Mun. Water Tank
First Flush
Filter
Bore Well
With Open Tap
122 Lit
With Mug & Bucket
10 Lit
Remember
We Wast Water
109.1 Lit/Day, 754.6 Lit/week
& 39712.0 Lit/Year
Through Dribbling Tap
With Open Tap
240 Lit
With Bucket
40 Lit
WATER IS PRECIOUS NATURAL RESOURCE AND NOT A COMMODITY

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